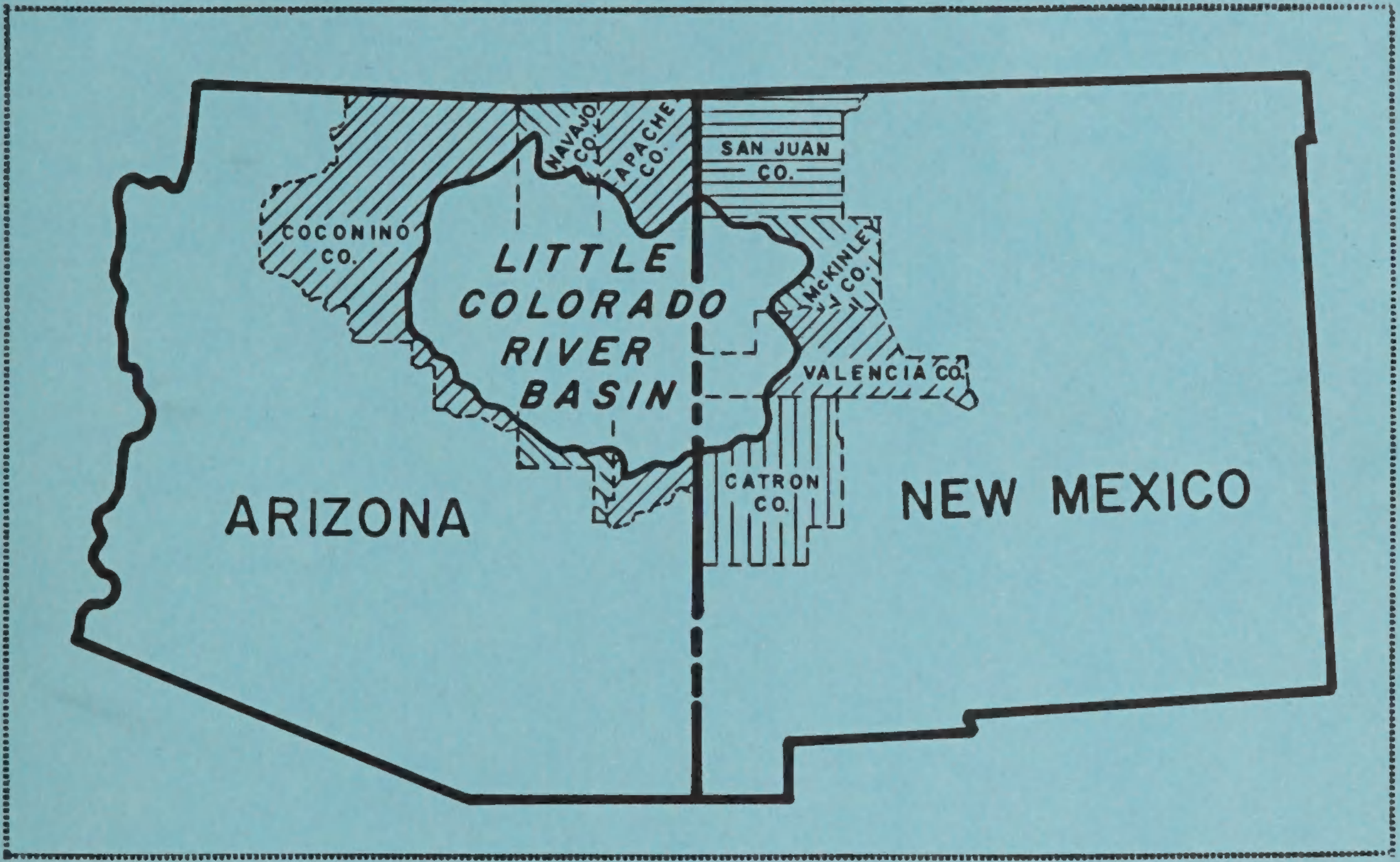
LITTLE COLORADO RIVER BASIN

ARIZONA-NEW MEXICO

APPENDIX II
WATER RESOURCES



U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ECONOMIC RESEARCH SERVICE
FOREST SERVICE

In cooperation with the states of
ARIZONA AND NEW MEXICO

December 1981

The "Water Resources" Appendix is one of four (4) such appendices which supplements and supports a "Summary Report". Titles and subsections of each appendice are as follows:

APPENDIX I: DESCRIPTION OF BASIN

- Section 1: Physical Description
- Section 2: Socio-Economic Base

APPENDIX II: WATER RESOURCES

- Section 1: Irrigation
- Section 2: Municipal and Industrial Water Supply
- Section 3: Rural Domestic and Livestock Water Supply
- Section 4: Development of Surface Water Resources
- Section 5: Surface Water Budgets (Including Pumped Groundwater)

APPENDIX III: EROSION AND SEDIMENT, AND FLOODING

- Section 1: Erosion and Sediment
- Section 2: Flooding

APPENDIX IV: RECREATION, FISH AND WILDLIFE, AND TIMBER

- Section 1: Recreation
- Section 2: Fish and Wildlife
- Section 3: Timber

LITTLE COLORADO RIVER BASIN

Cooperative Study

ARIZONA - NEW MEXICO

APPENDIX II

WATER RESOURCES

This appendix was prepared pursuant to Section 6 of the Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Congress, 68 Stat. 666, as amended and supplemented). The appendix presents information on five separate but interrelated subsections. These include Irrigation, Municipal and Industrial Water Supply, Rural Domestic and Livestock Water Supply, Development of Surface Water Resources, and Surface Water Budgets (Including Pumped Groundwater). The purpose of this Appendix is to present data on the basic water resources of the Basin, how they are presently being used, projected future uses, and problems related to the use of these resources.

LITTLE COLORADO RIVER BASIN
COOPERATIVE STUDY

ERRATA SHEET

1. Effective July 1, 1981, Valencia County, New Mexico, was divided into two counties. That portion within the Little Colorado River Basin became Cibola County.

2. In June 1981, the Economics and Statistics Service was reorganized to form the Economic Research Service and the Statistical Reporting Service.

3. The Arizona Water Commission is now the Arizona Department of Water Resources.

LITTLE COLORADO RIVER BASIN

COOPERATIVE STUDY

APPENDIX II

WATER RESOURCES

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IRRIGATION

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SECTION 1

IRRIGATION

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SECTION 1

IRRIGATION

INTRODUCTION

The production of crops in the Little Colorado River Basin is dependent upon irrigation. Historically, dry land commercial farming has been attempted in a few locations. One of the more prominent of these areas was in southern Navajo County, Arizona, just north of the Mogollon Rim between Heber and Show Low. While it is possible to occasionally find small fields of dryland crops, most have not proven to be financial successes, and after a few years the land is usually taken out of production.

There are numerous, very small plots of dryland Indian corn grown on the Navajo and Hopi reservations. This corn is not grown for the commercial market and yields are extremely low.

The purpose of this study was to determine the present use and projected needs for irrigation water; identify potential new supplies of water if needed; determine the potential of increasing irrigation efficiencies by applying conservation land treatment; to determine the potential for improving conveyance and distribution systems using USDA authorities; and to investigate the quality of water used for irrigation.

DEFINITION OF TERMS

Some of the terms used in this report are defined as follows:

Acre-foot: The amount of water that will cover one acre to a depth of 1 foot. Equals 43,560 cubic feet. Abbreviated AF.

Onfarm Losses: The water losses that occur at the time of field application. It includes seepage from field ditches, tailwater, and deep percolation.

CFS: Abbreviation for cubic feet per second. A unit of water flow. Sometimes called "second-feet."

Consumptive Use: Consumptive use, often called evapotranspiration, is the amount of water used by the vegetative growth of a given area in transpiration and building of plant tissue and that evaporated from adjacent soil or intercepted precipitation on the plant foliage in any specified time. If the unit of time is small, consumptive use is usually expressed as acre inches per acre or depth in inches, whereas, if the unit of time is large, such as a growing season or a 12-month period, it is usually expressed as acre feet per acre or depth in feet.

Conservation Cropping System: Rotation of crops in combination with needed cultural and management measures to improve or maintain good physical condition of the soil; protect the soil during periods when erosion usually occurs; help control weeds, insects, and diseases; and meet the need and desire of farms for an economic return.

Consumptive Water Requirement: The amount of water required to meet the evapotranspiration needs of vegetation so that plant production is not limited by lack of water.

Crop Residue Management: Use of plant residues to protect fields during critical erosion periods in order to conserve moisture; increase infiltration; reduce soil loss; and improve soil tilth.

Off-farm Conveyance Losses: The water losses that occur in an irrigation water conveyance system measured from the point of diversion to a farm. It includes losses from seepage, phreatophytes, and spills.

Effective Rainfall: Precipitation falling during the growing period, or directly effecting the growing period of the crop, that is available to meet the consumptive water requirements of crops. It does not include such precipitation as is lost to deep percolation below the root zone nor to surface runoff.

Irrigation Ditch And Canal Lining: A fixed lining of impervious material installed in an existing or newly constructed irrigation field ditch or irrigation canal or lateral.

Irrigation Efficiency: -- Off-farm conveyance efficiency is the ratio of the water delivered at the farm headgate to the total normal withdrawal.

-- Onfarm irrigation efficiency is the ratio of the seasonal irrigation requirement to the water delivered at the farm headgate.

-- Overall (Project) irrigation efficiency is the ratio of the seasonal irrigation requirement to the total normal withdrawal.

Irrigation Pipeline: A pipe or other closed conduit installed in an irrigation system.

Irrigation Requirement: The amount of irrigation water, expressed in terms of depth, that is required for crop production. In this report, it is defined as consumptive use minus effective rainfall at 80% probability.

Irrigation Water Management: Determining and controlling the rate, amount, and timing of irrigation water application to soils to meet consumptive use and leaching requirements in a planned and efficient manner so as to effectively utilize the available water supply to promote the desired crop response; to minimize soil erosion and loss of plant nutrients; to control undesirable water loss; and to protect water quality.

Land Leveling And Smoothing: Reshaping the surface of land to be irrigated to planned grades to permit uniform and efficient application of irrigation water without erosion, loss of water quality, or damage to land by waterlogging, and at the same time to provide for adequate surface drainage. Smoothing involves operations to remove irregularities on the land surface by rough grading.

Minimum Tillage: Limiting the number of cultural operations to those that are properly timed and essential to produce a crop and prevent soil damage in order to retard deterioration of soil structure, reduce soil compaction and formation of tillage pans; and to improve soil aeration, permeability, and tilth.

Normal Withdrawal: The average annual amount of water used for irrigation as measured from the point of diversion. It is the sum of the irrigation requirement, the off-farm conveyance losses, and the onfarm losses. It does not include reservoir storage or stream transmission losses.

Pasture And Hayland Management: Proper treatment and use of pastureland or hayland in order to prolong life of desirable forage species; to maintain or improve the quality and quantity of forage; and to protect the soil, and reduce water loss.

Water Use Area: In Arizona, the water use areas (WUA) are those defined by the Arizona Department of Water Resources (formerly the Arizona Water Commission) and the U. S. Geological Survey in their study of the groundwater resources for the state. Some minor modifications have been made in a few of the boundaries. In New Mexico, surface water drainage boundaries define the water use areas (see Irrigated Areas Map, following page 1-3).

DESCRIPTION OF IRRIGATED AREAS AND IRRIGATION WATER USE

The data presented in this section is based upon information supplied by the Soil Conservation Service (SCS) Field Offices and by various irrigation companies and districts. This was supplemented by interviews with local farmers and other individuals knowledgeable about the area, by a review of U. S. Geological Survey (USGS) gage records and publications, and by field studies.

A tabulation of the number of irrigated acres, irrigation requirement, water losses and irrigation withdrawals is shown in Table 1-1 page 1-17. The data is presented by separate "irrigated areas" and grouped by Water Use Areas (WUA). (See Irrigated Areas Map following page 1-4). A narrative description of conditions in the "irrigated areas," including acreages, storage facilities, source of water, and the rationale in arriving at the irrigation water withdrawals is presented in subsequent paragraphs of this section.

The breakdown of irrigated acreages is shown on Table 1-1, and includes two categories of irrigated lands; irrigated crops and native grass. There are several thousand acres of native grass in the Basin that are wild flooded to produce forage when excess surface water is available. This acreage is important in any water budget analysis, therefore, it is included in Table 1-1; but most of it is not included in Tables 1-2, 1-3, or 1-4. These latter tables deal with improvement programs for irrigated land. Approximately 1,880 acres of native grass at St. Johns, which are irrigated from an established irrigation system network with a fairly reliable water supply, are included in Tables 1-1 through 1-4.

An accurate determination of irrigation water use, including losses and total withdrawals, is difficult to determine for many areas in the Basin because there are only a few gages, and accurate measurement of irrigation water is the exception instead of the rule. The only recording gage on irrigation diversions in the entire Basin is on the Lyman Canal. There is also a problem of definition in the use of the terms "normal withdrawal" and "normal supply" when applied to surface water use in the Basin. Surface water is the primary source of water for irrigation and accounts for nearly two-thirds of the total irrigation use. Runoff is subject to wide fluctuations from year to year. In dry years, the normal withdrawal is essentially equal to the supply, and the total runoff is utilized. The number of acres under irrigation changes from year to year, depending upon how much water is available. In wet years, the supply exceeds withdrawals. This is due to two major reasons: (1) there is a shortage of storage capacity for complete regulation of runoff during wet years, and (2) diversion facilities are too small to handle large flows.

The procedures used by USDA to compute water withdrawals, as shown in Table 1-1, varied from area to area. The initial step for all areas was to use consumptive use analysis. The number of irrigated acres was determined along with cropping

patterns. Total withdrawal was then determined based on crop consumptive use and estimates of losses. This effort was followed by an analysis of gage records, reservoir storage records, interviews, yield analysis and field measurements. Adjustments were then made for some of the areas. The resulting data represents USDA's best estimate with the available information.

The irrigation water use data shown in Table 1-1 does not include estimates of losses for all irrigated areas nor are irrigation efficiencies shown. All users are urged to use caution if attempts are made to compute onfarm or project efficiencies from the data shown in Table 1-1. Expressions of onfarm and project efficiencies are meaningless and misleading whenever water supplies are less than the irrigation requirement and crops are stressed. Efficiencies are variable from year to year; often improving in drier years when water shortages forces better management. Several areas, particularly those in the higher elevations, have carryover moisture available in the soil profile from spring snowmelt. In effect, they receive a spring pre-irrigation. Often more acres are cropped than should be from the standpoint of a pure irrigation efficiency because farmers are willing to accept a reduction in yields per acre due to crop stress from lack of water. Some irrigated areas utilize tailwater or precolation from upstream fields; and crops use groundwater, particularly under highwater table conditions, when fields are adjacent to streams.

ARIZONA

White Mountains WUA

There are approximately 6,630 acres (see Table 1-1) of irrigated land in this Water Use Area (WUA). These lands are primarily concentrated along the Little Colorado River at Springerville and Eagar in southern Apache County, and along Show Low Creek and its tributaries at Pinetop, Lakeside, and Show Low in southern Navajo County.

Alfalfa and alfalfa-grass mixes, used for both hay and pasture, are the major crops produced. Other crops produced include small grain, corn silage, orchard, and truck crops. The normal irrigation water withdrawal is about 23,750 acre feet. This water is primarily from surface sources; however, some groundwater is pumped to augment these supplies.

This WUA has arbitrarily been divided into six separate irrigated areas. A discussion of each follows.

Show Low Irrigation Company: There are about 740 acres of irrigated land in the Show Low Irrigation Company. About 140 acres are located northwest of Lakeside and are shown in Table 1-1 as the "Lakeside Area." These lands are irrigated by diversion ditch from Lakeside Coffer Dam, which is on Walnut Creek immediately downstream of Rainbow Lake. The remaining 600 acres are located along Show Low Creek north of Jaques Dam (Show Low Lake) and near the City of Show Low. These are shown as the "Show Low Area" on Table 1-1. About 120 acres at Show Low are dry farmed at times because of lack of water. The primary source of water for the Show Low Area is by diversion from Show Low Creek, however, groundwater from three wells is sometimes used to supplement surface supplies.

The Show Low Irrigation Company stores irrigation water in six reservoirs: Pine Lake, Rainbow Lake, Lakeside Coffer Dam, Scotts Reservoir, and two Porter Springs

LEGEND

IRIGATED AREAS

MORTON

WATER USE AREAS

ARIZONA

BLM	Black Mesa Area
BOD	Bodaway Mesa Area
CDI	Canyon Diablo Area
CHV	Chevelon Area
CHN	Chinle Valley Area
CON	Concho Area
HOL	Holbrook Area
HOP	Hopi Area
KAI	Kaibito Plateau Area
PRZ	Puerco - Zuni Area
STJ	St. Johns Area
SFP	San Francisco Peaks Area
SNO	Snowflake Area
TUB	Tuba City Area
WHM	White Mountain Area
	NEW MEXICO
CAR	Carrizo Wash Area
UPR	Upper Puerco Area
ZUN	Zuni Area

NOTE:
In Arizona, Water Use Areas are Ground Water Study Areas; in Mew Mexico they represent Hydrologic Boundaries.

IRRIGATED AREAS
LITTLE COLORADO RIVER BASIN
ARIZONA AND NEW MEXICO

JANUARY 1980

10 0 10 20 30 40 MILES

SCALE 1:2,000,000

Source:
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series.
Thematic detail compiled by state staff.

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

M7-OL-24030-17

rearing ponds. The two major reservoirs are Rainbow Lake (1,200 AF) and Scotts Reservoir (1,450 AF). Rainbow Lake has a very stable water supply from Big Springs and Walnut Springs, plus some water from Adair Springs whenever it is not being used for irrigation in the Town of Lakeside (see write-up for Lakeside Town). The primary source of water for Scotts Reservoir is Porter Springs and snowmelt. The Show Low Irrigation Company also gets some water from Pinetop Springs on Billy Creek, however, most of this spring flow is diverted at Pinetop by the Pinetop-Woodland Irrigation District (see write-up on Pinetop-Woodland).

There are no gage records on the amount of water diverted from the Lakeside Coffer Dam for irrigation in the Lakeside area. Irrigation water rights call for 2.5 cfs continuous flow, which is almost equivalent to the flow of Big Springs (2.23 cfs). Based upon this data, USDA estimates the probable irrigation water withdrawal for the Lakeside Area to range from a minimum of 770 AF/year to a maximum of 1,650 AF/year. A reasonable value is about 910 AF/year (see Table 1-1).

The Show Low Area obtains water from Show Low Creek via a diversion downstream of Show Low Lake. There is no storage for irrigation in Show Low Lake. Waters from upstream reservoirs, primarily Rainbow Lake and Scotts Reservoir, are passed through Show Low Lake for downstream irrigation use. The USGS has gaging stations both upstream and downstream of Show Low Lake. The downstream gage is located just upstream from the diversion.

An analysis of gage records shows that the average April-September flow past the downstream gage for an 8-year period between 1967 and 1976 is 1,790 AF. The high runoff years of 1973 and 1975 were not included in this computation. All of the flow past the gage cannot be diverted by the Show Low Irrigation Company because high flows exceed the capacity of the diversion. In 1979, the irrigation company converted the main canal from unlined ditch to a steel and plastic pipeline designed for 5 cfs.

USDA estimates the probable range of water withdrawls for the Show Low Area to be 1,400 AF/year to 1,800 AF/year with 1,500 AF/year as a reasonable average. There is also about 50 AF/year of groundwater used (see Table 1-1).

Lakeside Town: There are about 100 acres of pasture, garden, and orchard within of Lakeside irrigated by pipeline from Adair Springs. USDA has measured the flow of Adair Springs at a fairly constant 0.5 cfs. The normal irrigation withdrawal is estimated to be 170 AF/year (see Table 1-1).

Pinetop-Woodland: There are about 190 acres (primarily of pasture, garden, and orchard) located at Pinetop and in the Woodland Area northwest of Woodland Reservoir. The water supply for this land is by a diversion on Billy Creek to capture flows from Pinetop Springs and storage in Woodland Reservoir. USDA estimates the normal irrigation withdrawal for this area to be 480 AF/year. This value was determined by adding the flow diverted at Billy Creek (340 AF/year) and the storage in Woodland Reservoir (140 AF).

Springerville-Eagar: This area is defined as the irrigated lands in and near the communities of Springerville and Eagar in southern Apache County. There are about 3,210 acres in this area. This includes 1,980 acres in the Round Valley Water Users Association, 60 acres in the Springerville Water Rights and Ditch Company, 500 acres east of Springerville, 500 acres southwest of Springerville and 170 acres on Water Canyon.

The water supply is 98% surface with diversions from the Little Colorado River, Water Canyon, and Nutrioso Creek. Irrigation storage on the Little Colorado River and its tributaries totals about 4,820 AF in White Mountain Reservoir, River Reservoir, Tunnel Reservoir and Bunch Reservoir. On Water Canyon, the irrigation storage is about 830 AF at Slade, Atchison, Rudd, Russel, Water Canyon, and Rencher No. 5 reservoirs.

The amount of irrigation water withdrawn in the Springerville-Eagar Area is subject to the Norviel Decree of 1918 and subsequent judgments. The Decree established the period April 15 to September 15 as the irrigation season and the period September 15 to April 15 for reservoir filling. The Decree also established the water rights on the Little Colorado River and its tributaries upstream from St. Johns and established priorities for filling of irrigation reservoirs.

There are insufficient records of water flow to allow accurate determination of the amount of water used for irrigation in this area. Several of the irrigation ditches have Parshall flumes or similar measuring devices to establish flow rates in compliance with the Norviel Decree, however, records on total volume of flow are not kept.

USDA used the records of the USGS gaging station on the Little Colorado River at Greer in combination with reservoir storage data and yield analysis to estimate the average irrigation water withdrawal in the Springerville-Eagar Area to be about 12,850 AF/year. This value is the sum of the average flow during the irrigation season on the Little Colorado River at Greer (5,950 AF) 1/ plus 70% of the available reservoir storage (3,970 AF) plus an estimated 2,930 AF/year contributed by South Fork, Hall Creek, Fish Creek, Nutrioso Creek, Water Canyon, and other tributaries. There are also about 260 AF/year of groundwater used for irrigation in this area (see Table 1-1).

Nutrioso Area: This area includes irrigated lands at Nutrioso and along Rudd, Colter, Riggs and Auger Creeks. There are about 1,500 acres in this area.

The water supply is 100% surface. Irrigation storage totals about 650 AF at Rogers, Finch-Giles, Nutrioso, Jarvis, San Salvador, St. Mary's, McKay, Glen Levit, and Trinity reservoirs.

There are no gage records on the amount of irrigation diversions in the area. USGS has a gage above Nelson Reservoir, however, it is downstream of most of the irrigated lands, and thus, could not be used to determine withdrawals.

USDA estimates the average irrigation withdrawal in this area to be 3,950 AF/year. This value was determined from yield analysis and known storage capacity for the irrigation reservoirs.

White Mountain Other: This designation includes other minor acreages in the White Mountain WUA at widely separated locations, all within Apache County. It includes 260 acres at Greer irrigated by diversion from the Little Colorado River, 230 acres north of Greer irrigated by diversion from 24 Draw and Carnero Creek, 300 acres at Vernon irrigated by diversion from Mineral and Sepulveda creeks, and approximately 100 acres on Morrison Creek east of Springerville. The total is approximately 890 acres.

1/ The 9-year April-October flow past this gage for the period of 1967 to 1976 (1973 not included) is 6,980 AF. USDA estimates 1,030 AF of the flow is used at Greer, resulting in the value of 5,950 AF as shown above.

Storage for irrigation on 24 Draw and Carnero Creek at Geneva, Norton, Ellis Wiltbank, Wiltbank Nos. 1, 2, 3, and 4 reservoirs and Carnero Lake totals approximately 1,005 AF. The storage on Morrison Creek at Towser Reservoir and Conservation Reservoir Nos. 1 and 2 is approximately 440 AF.

There are no records of irrigation water withdrawals in this area. USDA estimates the normal withdrawal to be about 4 AF/acre/year for a total of 3,580 AF/year. This includes 1,190 AF at Vernon, 1,030 AF at Greer, 920 AF from 24 Draw and Carnero Creek and 440 AF on Morrison Creek.

Concho WUA (Con)

There are about 2,130 acres of irrigated cropland in this WUA. Alfalfa and alfalfa-grass mixes, used for both hay and pasture, are the major crops produced. Minor crops include orchard, gardens, and pinto beans. There are also about 4,600 acres of native grass that are wild flooded when water is available. All of the irrigated lands in this WUA are in Apache County. The water is from surface and ground sources.

This WUA has been arbitrarily divided into three irrigated areas. A discussion of each area follows.

Concho: This area includes 450 acres irrigated at Concho within the Concho Irrigation Company plus 600 acres of native grass on the Chilcott Ranch irrigated when water is available from Ortega Lake.

The Concho Irrigation Company obtains its water from Concho Lake which has a capacity of about 1,150 AF. The lake is fed by Concho Springs, one of the best springs in the area. The spring discharge is fairly constant at about 2.7 cfs. Based upon the spring flow and storage in Concho Lake, USDA estimates the annual irrigation withdrawal to be 1,500 AF/year.

Ortega Lake is a large sink. It is the termination point of Mineral Creek. Most of the water supply is from snow melt. USDA estimates that about 600 AF/year are used under normal conditions for irrigation of native grass (see Table 1-1). No estimates have been made for losses since this is considered inappropriate for wild flooding on native grass because the irrigation system is not formally defined. In essence, the amount applied equals withdrawals.

Hunt: There are about 1,040 acres of pastured hay irrigated from wells at Hunt. By consumptive use analysis, USDA estimates the irrigation withdrawal to be about 5,270 AF/year.

There are also 4,000 acres of native grass irrigated by wild flooding from the Little Colorado River when water is available. Based upon yield analysis, it is estimated that 4,000 AF/year is withdrawn. No estimates have been made of losses (see Table 1-1).

Concho Other: This grouping involves a total of 640-acres at three separate areas in western Apache County. It includes 375 acres in Section 4, T13N, R25E, NW of Concho irrigated by sprinkler and flood; 230 acres west of Hunt in T14N, R24E; and 35 acres at Hay Hollow. Based upon consumptive use analysis, irrigation withdrawals are estimated at 2,440 AF/year, entirely from groundwater.

St. Johns WUA (STJ)

This WUA covers the irrigated lands along the Little Colorado River from Richville to St. Johns, and lands in the vicinity of St. Johns within the Lyman Water Company, the St. Johns Irrigation Company, and at Zion Reservoir. All of this land is in Apache County.

There are about 5,640 acres of irrigated land in this WUA, including 2,940 acres of cropland and 2,700 [1/] acres of native grass pasture. The principal crops are alfalfa for hay with minor amounts of small grain, orchard and gardens.

The water supply is primarily surface water diversions from the Little Colorado River, although there is some supplemental pumping.

This WUA has been divided into four irrigated areas. A discussion of each area follows.

Lyman Water Company: There are about 2,200 acres of cropland within this company at St. Johns and vicinity. The main source of water is Lyman Lake, a major impoundment on the Little Colorado River with a storage of 30,600 AF. The company also has upstream storage in the higher elevations totaling approximately 2,620 AF at Hog Wallow Lake, Pool Corral Lake, Mexican Hay Lake, and Colter Reservoir.

Surface water diversions are supplemented by three wells pumping into the Lyman Canal. Two of the wells are immediately downstream from Lyman Dam and the other is at Salado. The water from this well is high in salts. The three wells are seldom used. Groundwater withdrawal is estimated at about 300 AF/year.

The USGS maintains a gage with a continuous recorder to measure flows in the Lyman Canal. Gage records show a 25-year average diversion of 8,400 AF/year. When available, up to 400 AF/year of this water is passed through to Little Reservoir for use by the St. Johns Irrigation Company, which leaves 8,000 AF/ year as the average surface water withdrawal by the Lyman Water Company.

St. Johns Irrigation Company: There are approximately 2,000 acres in this company, including 120 acres of primarily orchard and garden, and 1,880 acres of native grass pasture. As previously mentioned, all of this acreage is considered as irrigated cropland in Tables 1-1 through 1-4 because the irrigation system network is formally established as opposed to other areas of native grass; system improvements are needed, and the water supply is fairly constant.

This company receives up to 400 AF/year of good quality water from Lyman Dam via Lyman canal and a feeder ditch to Little Reservoir. They also have two diversions on the Little Colorado River, both of which are downstream from the point where the highly saline waters of Salado Springs enter the river.

One diversion diverts water to Little Reservoir where it is mixed with better quality water from Lyman Canal. This water is then used primarily to irrigate orchards and gardens within the City of St. Johns. Most of the main distribution system within the city is pipeline.

1/ Includes 1880 acres of native grass in the St. Johns Irrigation Company Project Area in addition to the 820 acres in the Zion Reservoir area. (See St. Johns Irrigation Company write-up).

The other diversion, located approximately 500 feet south of where State Highway 61 crosses the Little Colorado River, diverts water out of both sides of the river through a system of unlined canals. This water, of poor quality due to Salado Springs, is used to irrigate native grass in areas generally north and northeast of St. Johns. The water comes from two sources; Salado Springs and flow in the Little Colorado River originating either as seepage through Lyman Dam or releases from the dam that are not diverted via Lyman Canal.

To determine the amount of flow from Salado Springs, USDA analyzed peak flow measurements on the Little Colorado River at points upstream and downstream of the Springs. The difference in these readings is assumed to be representative of the discharge from Salado Springs. This analysis shows the flow of Salado Springs to be in the range of 5.0-7.5 cfs, depending upon the time of year. For the purpose of this report, the average annual discharge was assumed to be 5.0 cfs. This converts to 3,650 AF/year.

Flow from Lyman Dam was estimated based on the analysis of the USGS stream gage located downstream from Lyman Dam, but upstream of Salado Springs. The 33-year period of record for this gage shows an average annual flow of 2,350 AF/year.

Water from Lyman Dam and Salado Springs is applied to the native grass yearlong, regardless of need, because there are no storage reservoirs (other than Little Reservoir) to regulate flow.

In summary, the amount of surface water withdrawn (annually) by the St. Johns Irrigation Company is:

Little Reservoir via Lyman Canal		400 AF/year
Salado Springs		3,650
Little Colorado River Passing Gage D/S of Lyman Dam		2,350
	Total:	6,400 AF/year

There is also a minor amount of groundwater pumping by the St. Johns Irrigation Company, however, this is seldom done. USDA estimates the groundwater withdrawal at about 200 AF/year.

Zion Reservoir: There are about 820 acres of native grass located approximately one mile east of Zion Dam. The grass is irrigated by diversion from the Little Colorado River. The water comes from tailwater and seepage from upstream irrigated lands at St. Johns. USDA estimates the irrigation withdrawal here to be 820 AF/year. No estimates have been made for losses (see Table 1-1).

Richville: There are about 620 acres along the Little Colorado River from Richville to near Lyman Lake. The surface water is obtained by diversion from the Little Colorado River. There are also a few wells. USDA estimates the surface water and groundwater withdrawals at 3,100 AF/year and 200 AF/year respectively. The surface withdrawal is equivalent to 5.0 AF/acre/year.

Canyon Diablo WUA (CDI)

There are approximately 1,100 acres of irrigated land in this WUA, including 420 acres in Navajo County at Winslow and 680 acres in Coconino County at Turquoise Ranch, Chilsom (Bar-T-Bar) Ranch and near Morton Lake.

The principal crops are alfalfa and pasture with some corn and other crops. The water supply is primarily surface.

The irrigation requirement is estimated at 2,010 acre feet. Off-farm conveyance and onfarm water losses amount to 1,280 and 1,820 AF respectively. Overall irrigation efficiency is about 39%.

This WUA has been divided into two areas, Winslow and Canyon Diablo Other. A discussion of these areas follows.

Winslow: There are approximately 420 acres of irrigated land at Winslow that are normally irrigated, including 160 acres utilizing groundwater and 260 acres utilizing surface water. There is an additional 280 acres at a proposed City Park Site that is sometimes irrigated when water is available. This latter area is not included in Table 1-1. In the past, the Chevelon Irrigation Company diverted water from Chevelon Creek to irrigate 180 acres at Bushman Acres. This area is now subdivided and the irrigation system is no longer in use.

The 160 acres using groundwater include 100 acres with an excellent distribution system having all gated pipe, and 60 acres with a poor distribution system. USDA estimates the groundwater withdrawal for all of this land to be 640 AF/year.

The surface water supply comes from Clear Creek via a diversion at Clear Creek Reservoir. The irrigation canal is largely unlined and losses are high. There are no gage records on the amount of irrigation diversions. The USGS maintains a recording gage at Clear Creek Dam; however, it only records flows that pass the structure.

USDA estimates the irrigation withdrawal from Clear Creek to be 1,760 AF/year. This value is based upon consumptive use and estimated losses in the off-farm conveyance and onfarm systems.

Canyon Diablo Other: This grouping totals 680 acres, including 100 acres at Turquoise Ranch, 500 acres at Bar-T-Bar Ranch and 80 acres irrigated from Morton Lake. All of the land is in Coconino County.

Turquoise Ranch is located on Interstate 40 west of Winslow. Normal cropping patterns involve about 50 acres of small grain and 50 acres of hay and pasture. This land is flood irrigated, utilizing groundwater from 2 wells. USDA estimates groundwater withdrawals to be 400 AF/year. This value is based on consumptive use procedures.

The Bar-T-Bar Ranch is located southeast of Flagstaff. There are about 500 acres of pasture under basin leveling that are irrigated when water is available. The water comes from Tremaine Lake. Supply is highly variable depending upon runoff. USDA estimates surface withdrawals to be 2,020 AF/year.

Morton Lake is an irrigation storage reservoir for lands located NE of the lake. USDA estimates the surface withdrawal to be about 290 AF/year. This value is based solely upon the available storage in Morton Lake as there are no records on the amount of water used for irrigation in this area.

Holbrook WUA (HOL)

There are approximately 4,250 acres of irrigated land in this WUA. This includes 740 acres at Holbrook, 1,500 acres at Joseph City, 1,610 acres at Hay Hollow and

400 acres at Woodruff. All of this land is in Navajo County. Alfalfa and alfalfa-grass mixes, used for hay and pasture, are the principal crops. Other crops include corn for silage, small grain, and truck crops. Both groundwater and surface water are used for irrigation. This WUA has a water deficit of about 3,210 AF/year at Joseph City.

This WUA has been divided into four areas. A discussion of each follows.

Holbrook: There are about 740 irrigated acres at Holbrook. The water supply is 100% groundwater with wells tapping the Little Colorado alluvium and underlying Coconino aquifer. Most of the irrigated lands are under sprinkler. USDA estimates the irrigation withdrawal to be 2,590 AF/year. This value was determined by consumptive use analysis and estimates of losses.

Joseph City: There are about 1,500 acres developed for irrigation at Joseph City, however,due to shortage of water, only 500-600 acres are normally cropped. The water supply is primarily from groundwater, although some surface water is used by diversion from the Little Colorado River. There are presently no storage facilities to regulate surface water supplies.

The Joseph City Irrigation District estimates that 2,193 AF of groundwater was pumped for irrigation in 1973. The USGS estimates that approximately 1,075 AF were used in 1977.

USDA assumes the values of 2,200 AF/year of groundwater pumpage plus 900 AF/year of surface diversions from the Little Colorado River as reasonable estimates of the irrigation withdrawals at Joseph City. Based on consumptive use requirements and estimates of off-farm conveyance and onfarm losses, the total withdrawal of 3,100 AF/year of water use can adequately irrigate approximately 750 acres with existing cropping patterns (see Table 1-1). An additional 3,210 AF/year is needed to adequately irrigate the full 1,500 acres that are developed. This value could be reduced with an improvement in efficiencies.

Hay Hollow: Hay Hollow is northeast of Snowflake. There is a total of 1,645 acres in this area, however, 35 acres are in Apache County and were previously discussed under the "Concho Other" Irrigated Area. Of the remaining 1,610 acres in the Holbrook WUA, approximately 1,120 acres are sprinkler irrigated. The water supply for the sprinkler systems and other irrigated land is entirely groundwater. USDA estimates the groundwater withdrawal to be 5,790 AF/year. This value was determined by consumptive use analysis and estimates of losses.

Woodruff: There are about 400 acres of irrigated land at Woodruff. The farmers here have tried several different methods to get water to their land which is above the gorge of the Little Colorado River. The original effort was a large dam across the gorge. This failed in 1916 when Lyman Dam broke. The farmers then constructed Woodruff Dam on Silver Creek and directed the sediment-free water of Silver Creek to Woodruff via a complex system of flumes, canals and siphons that traversed the Little Colorado River gorge. This was finally abandoned in the 1950's because of high maintenance costs.

The present system is a turbine pump mounted on the east canyon wall of the Little Colorado River gorge plus a well drilled into the Coconino aquifer.

Based upon information provided by the Woodruff Irrigation District, the normal irrigation withdrawal is about 1,670 AF/year, of which 500 AF/year is surface water pumped from the Little Colorado River and 1,170 AF/year is groundwater. The off-farm conveyance efficiencies at the present time are about 80% and should improve as pipelines are installed on more of the system.

Snowflake WUA (SNO)

There are approximately 4,700 acres of irrigated land in this WUA of which all but 190 acres are in the vicinity of Shumway, Taylor and Snowflake.

Alfalfa and alfalfa-grass mixes, used for both hay and pasture, are the principal crops. Other crops include corn for silage, small grain, and truck crops. Both groundwater and surface water are used for irrigation.

This WUA has been divided into three areas. A discussion of each follows.

Snowflake-Taylor: This grouping involves approximately 2,240 acres in the vicinity of Shumway, Taylor and Snowflake, of which all but about 50 acres south of Shumway are within the Show Low-Silver Creek Water Conservation and Power District.

This District gets its irrigation water from Silver Creek which is supplied by Silver Springs, the largest spring in the area. The principal storage is at Daggs Reservoir (White Mountain Lake), a large reservoir on Silver Creek; and Mexican Lake, which receives high stage overflow from Daggs Reservoir via a connecting ditch. There is also some storage available in wet years at Martinez Lake, a shallow off-channel impoundment on Brown Creek, and at Lone Pine Reservoir on Show Low Creek. Neither of these latter two reservoirs are very dependable; Martinez Lake has high evaporation losses and Lone Pine Reservoir has high seepage losses. There are seven canals where water is diverted out of Silver Creek including six District canals and the Bert Soloman Diversion.

The water supply is primarily surface, although the District has six wells taking groundwater from the Silver Creek alluvium. These are shallow wells utilizing electric turbine pumps. They border Silver Creek and pump directly into the creek where the water is picked up by diversion dams. These wells were installed through an agreement with a subdivision developer at White Mountain Lake, exchanging the wells for the right to keep a 15-foot depth recreation pool in the lake. Based on well flow measurement, it is estimated that about 3,000 AF/year of groundwater is normally withdrawn by the wells. They are only used whenever surface supplies cannot meet irrigation needs.

USDA estimates the normal surface water withdrawal to be 8,300 AF/year. This value is the sum of three items; the storage in Daggs and Mexican Lakes, the flow of Silver Creek during the irrigation season, and an estimated flow from Show Low Creek.

The gross storage in Daggs and Mexican Lake is 5,000 AF. Subtracting the dead storage in Mexican Lake (580 AF) and the minimum recreation pool in Daggs (900 AF) leaves a net available for irrigation of 3,520 AF.

The April-October inflow to Daggs from Silver Creek is estimated at 4,190 AF. This value is based on streamflow analysis made by the U. S. Bureau of Reclamation for the period 1929-1944 in connection with the Bureau's investigation for the proposed Shumway Dam.

Based on yield analysis, the estimated annual withdrawal from Show Low Creek is about 590 AF/year.

In summary, the estimated surface withdrawal of 8,300 AF/year is the sum of the 3,520 AF of storage in Daggs and Mexican lakes, 4,190 AF from Silver Creek, and 590 AF from Show Low Creek.

Snowflake Wells: There are 2,270 acres of irrigated land near Snowflake and Taylor that use groundwater. These lands are not within the Show Low-Siver Creek Water Conservation and Power District. Water withdrawals are estimated to be 8,060 AF/year. The value was determined by consumptive use analysis and estimates of losses.

Pinedale and Dry Lake: There are 110 acres at Pinedale and 80 acres at Dry Lake that use groundwater for irrigation. Although the Dry Lake lands use waste water from the Snowflake Pulp Mill, it is considered as a groundwater withdrawal, since the original use was from this source.

Water withdrawals are estimated to be 960 AF/year. This value was determined by consumptive use analysis and estimates of losses.

Other Water Use Areas

There are four WUA's included in this grouping: the Puerco-Zuni Area (PRZ), Tuba City (TUB), San Francisco Peaks Area (SFP), and Chinle Valley (CHN). The total irrigated area is estimated at 820 acres. Alfalfa, pasture and corn are the principal crops grown.

Water withdrawal is about 5,020 AF/year. Most of the water supply is from surface sources; however, groundwater and sewage return flows are used in some areas. Following are descriptions of the irrigated lands in the four WUA's.

Puerco-Zuni WUA: There are 340 irrigated acres in this WUA, including 180 acres at Adamana and 160 acres at Chambers. The normal withdrawal, estimated at 1,700 AF/year, is entirely from groundwater. This value was determined by consumptive use analysis and estimates of losses.

Tuba City WUA: There are 250 irrigated acres in this WUA located at Moenkopi. The water supply comes primarily from Pasture Canyon Dam with some from sewage return flows. The total withdrawal, considered 100% surface, is estimated at 530 AF/year. This value was determined by yield analysis.

San Francisco Peaks WUA: There are 40 irrigated acres in this WUA, located at Doney Park northeast of Flagstaff. The water supply is sewage return. The total withdrawal, based on estimates of discharge, is about 170 AF/year. This is considered as all surface water, although the original source of some of the sewage return was undoubtedly groundwater.

The only other area of possible irrigation withdrawal in this WUA is water used for a golf course at Continental Country Club at Flagstaff. The source of this irrigation water is sewage return. The amount of water used was not determined and is not included in this report.

Chinle Valley WUA: There are 190 acres in this WUA, including 60 acres at Ganado and 130 acres at Red Lake.

The water supply comes from Ganado Lake and Red Lake. Both lakes are rather shallow and have high evaporation losses.

The total withdrawal for both areas is estimated at 2,620 AF/year. This value was determined by consumptive use analysis and estimates of normal storage in Ganado and Red Lakes.

NEW MEXICO

In the New Mexico portion of the Basin there are approximately 4,950 acres of irrigated cropland. The term "irrigated cropland" is defined as the sum of irrigated acreage of planted crops, diverted acreages, and idle or fallow acreage. It also means that acreage is developed and irrigation works exist to apply water to the land.

Ordinarily, not all the irrigated cropland acreage is planted every year due to water shortages. During the base year, the acreage irrigated was about 2,520 acres (see Table 1-1A). The term "acreage irrigated" or "irrigated acres" means land planted to crops and receiving irrigation water during the growing season.

Irrigation data presented in this section is based upon information supplied by varied sources including the Soil Conservation Service (SCS) field offices, Bureau of Indian Affairs (BIA) offices located in the area, and various bulletins, research reports and technical reports published by New Mexico State University and by the New Mexico State Engineer. Irrigated acres as shown in Table 1-1A come from SCS field office records and from New Mexico State University Research Report No. 405(13). Consumptive irrigation requirements (CIR) values used to determine irrigation requirements in Table 1-1A were taken from New Mexico State University Bulletin 531(12) and from the New Mexico State Engineer.

Off-farm conveyance and onfarm efficiencies used are the best estimates the USDA can determine with the information available. There are no gages to measure irrigation diversions. Local experience and data presented in Technical Report No. 32(5) were used to estimate losses.

Zuni WUA (ZUN)

There are approximately 4,170 acres of irrigated cropland in this WUA (Hydrologic Unit in New Mexico), but not all the acreage is irrigated every year. These lands are located along the Zuni River or its tributaries, the Pescado and Nutria Creeks, or other small drainages leading into the Zuni River. During the base year about 2,120 acres were irrigated. Most of the land is in McKinley County except for about 570 acres which are in Valencia County.

Principal crops grown are alfalfa, small grains, corn, garden crops and some irrigated and/or native pasture. The normal irrigation water withdrawal is estimated at about 9,800 acre feet. This water is mostly from surface water sources except in the Page area southeast of Gallup, New Mexico, where groundwater was pumped in the past to irrigate approximately 200 acres.

Consumptive irrigation requirements for the crops grown in 1975 was estimated at 3,200 acre feet. Off-farm conveyance and onfarm water losses were 3,220 acre feet and 3,380 acre feet respectively. The overall irrigation efficiency is about 33 percent.

This WUA has been divided into four separate irrigated areas. A discussion of each follows.

Zuni: This irrigated area is within the Zuni Indian Reservation. There are five separate units; each unit has one or more reservoirs which store irrigation water. Four units are in McKinley County (Nutria, Pescado, Tekapo, and Zuni) and one unit is in Valencia County (Ojo Caliente). The five units have approximately 2,600 acres of irrigated cropland; however, only about 1,400 acres were irrigated during the base year. Average irrigation water supply is generally inadequate, throughout the irrigation season, for the total acreage, therefore, only a portion of the irrigated cropland is irrigated. This acreage varies from year to year depending on the available water supply. Eight irrigation reservoirs are located upstream from the five irrigated units. They have a maximum capacity of about 7,780 acre feet. Principal crops grown are corn, alfalfa, and small grains.

Ramah Land and Irrigation Company: This irrigated area is located approximately 40 miles southeast of Gallup in McKinley County. The area is irrigated by surface flows with water stored in Ramah Reservoir. Storage capacity in the reservoir is normally adequate, however, irrigation water supply is generally inadequate and the irrigated acreage varies from year to year depending mostly on the available water supply. The Ramah Land and Irrigation Company has 1,200 acres of irrigated cropland, however, during the base year, only about 550 acres were irrigated. Principal crops grown are alfalfa, small grains, and irrigated pasture.

Nicoll's Lake Area: This irrigated area is located about seven miles south of El Morro National Monument in Valencia County. Approximately 170 acres can be irrigated from water stored in Nicoll's Lake which has a storage capacity of about 625 acre-feet. Generally, irrigation water supply is inadequate, although there are years of adequate supply when the storage reservoir fills to capacity.

Page Area: This irrigated area is located approximately 32 miles southeast of Gallup, New Mexico and about 7 miles from Page in McKinley County at an elevation of about 7,300 feet above sea level. The McKinley County profile of the Water Resource Assessment Report (9) shows 200 acres of land irrigated from groundwater. This area has been irrigated in the past, but there was no evidence of irrigation during the base year. It is unknown if the area will again be irrigated. Principal crops that can be grown are small grains and irrigated native grass pasture.

Carrizo Wash WUA

Mangas Springs Area: This area is located about 16 miles southeast of Quemado, New Mexico, in Catron County, and is the only irrigated area in the WUA. About 170 acres can be irrigated from Mangas Creek and from springs in the area. About 10 acres are irrigated from groundwater. Water is stored in small farmtype storage reservoirs, which are not large enough to store irrigation requirements.

Shortages are common during years of inadequate snowpack. The water assessment report (9) shows a total of 180 acres of irrigated cropland in the Mangas Springs area; however, only 100 acres were irrigated during the base year. Principal crops are irrigated native pasture and small grains for grazing purposes.

The average consumptive irrigation requirement (CIR) taken from New Mexico State University Bulletin 531(12) and applied to the selected cropping pattern was used to compute a weighted CIR. Then, it was estimated that the consumptive irrigation requirements needed to be reduced by 25 percent due to water shortages during the latter part of the irrigation season. The reduced weighted CIR and and estimated losses were used to compute the normal withdrawal shown in Table 1-1A.

Consumptive irrigation requirements were estimated at about 100 acre-feet for 100 acres of land irrigated. Off-farm conveyance and onfarm losses were estimated to be 70 and 180 acre-feet, respectively.

Upper Puerco WUA

Navajo, Western Part McKinley County: This area is located about 15 miles north of Window Rock, Arizona, below Red Lake along the Arizona New Mexico State line. The county profile for McKinley County in the Water Resources Assessment Report (9) shows 600 acres of irrigated cropland in the western part of McKinley County, Navajo Reservation. In recent years, evidence indicates that about 300 acres have been irrigated. The conveyance system is being improved. Principal crops are corn, alfalfa, small grain, and grass pasture.

Consumptive irrigation requirement for 300 acres of cropland is estimated to be about 460 acre-feet. Estimated off-farm conveyance and onfarm losses are 390 acre-feet and 460 acre-feet respectively. Overall irrigation efficiency is 35 percent.

PROBLEMS AND NEEDS

OFF-FARM STORAGE AND CONVEYANCE SYSTEMS

Off-farm systems are defined as irrigation water storage facilities and related conveyance mains and appurtenant devices that are utilized to transport water from the source to a land ownership boundary. The storage facilities within the Basin are lakes or manmade reservoirs. Conveyance mains consist primarily of pipelines and earthen and concrete lined canals and ditches with appurtenant gates, checks, valves, pumps and other control devices, and lateral ditches and pipelines used to distribute the water to various points of use. Off-farm systems are rarely individually owned, but rather owned by a district, association, water company, or other formal group of water users united by the common need for irrigation water in a common area of diverse ownership.

Arizona

The off-farm storage and conveyance systems within the Basin are generally adequate. There are four irrigated areas that have problems with their off-farm systems where USDA recommends immediate action; West Taylor, Springerville, Pinetop-Woodland, and Joseph City. The first three areas are discussed in the Opportunities For USDA Programs Section of this report. A discussion of the needs at Joseph City follows. None of the other conveyance systems that were reviewed in this study had problems great enough to warrant immediate attention. This does not mean that the systems cannot be, or should not be, improved. The total improvement needs for conveyance systems and other land treatment, by water use area, are shown in Table 1-2.

Joseph City Irrigation Company: The Joseph City area has a water deficiency. The company has not been able to fully draw upon their rights to Little Colorado River water due to lack of storage facilities. The company plans to construct a reservoir that would be filled by diverting water out of the Little Colorado River. This reservoir would reduce the existing supply deficiency. The company decided not to construct the reservoir at this time and deficiencies are expected to continue in the future.

Table 1-1: Existing Conditions
Irrigation Water Use Data by Water Use Area
Little Colorado River Basin, Arizona Portion

Water Use Area Irrigated Area	Irrigated Acres (AC)	Irrigation Requirement 1/ (AF)	Normal Losses 2/ Off-Farm Conveyance (AF)	Normal Losses 2/ OnFarm (AF)	Normal Losses 2/ Total Losses (AF)	Normal Seasonal Withdrawal 3/ Surface (AF)	Normal Seasonal Withdrawal 3/ Ground (AF)	Normal Seasonal Withdrawal 3/ Total (AF)
WHITE MOUNTAINS WHM)								
Show Low Irrigation Co.								
Lakeside Area	140	180	550	180	730	910	-	910
Show Low Area 4/ 5/	600	890	460	200	660	1,500	50	1,550
Lakeside Town	100	110	10	50	60	170	-	170
Pinetop-Woodland 4/ 6/	190	250	160	70	230	480	-	480
Springerville-Eager 4/	3,210	5,060				12,850	260	13,110
Nutrioso Area 4/	1,500	2,430				3,950	-	3,950 7/
White Mountain Other 4/	890	1,450				3,580		3,580 8/
Sub-Total	6,630	10,370				23,440	310	23,750
CONCHO (CON)								
Concho 4/								
Crops	450	860				1,500	-	1,500 9/
Native Grass	600	600	-	-	-	600	-	600
Hunt								
Crops	1,040	2,230	1,840	1,200	3,040	-	5,270	5,270
Native Grass	4,000	4,000	-	-	-	4,000	-	4,000
Concho Other	640	1,370	610	460	1,070	-	2,440	2,440
Sub-Total	6,730	9,060				6,100	7,710	13,810
ST. JOHNS (STJ)								
Lyman Water Company 4/	2,200	4,930				8,000	300	8,300 10/
St. Johns Irrigation Co.	2,000	2,000	2,970	1,630	4,600	6,400	200	6,600 11/
Zion Reservoir								
Native Grass	820	820	-	-	-	820	-	820
Richville	620	1,330	1,320	650	1,970	3,100 12/	200	3,300
Sub-Total	5,640	9,080				18,320	700	19,020
CANYON DIABLO (CDI)								
Winslow	420	1,050	970	380	1,350	1,760	640	2,400
Canyon Diablo Other	680	960	310	1,440	1,750	2,310	400	2,710
Sub-Total	1,100	2,010	1,280	1,820	3,100	4,070	1,040	5,110

Table 1-1: Existing Conditions
Irrigation Water Use Data by Water Use Area
Little Colorado River Basin, Arizona Portion
(continued)

Water Use Area Irrigated Area	Irrigated Acres (AC)	Irrigation Requirement 1/ (AF)	Normal Losses 2/ Off-Farm Conveyance (AF)	Normal Losses 2/ OnFarm (AF)	Normal Losses 2/ Total Losses (AF)	Normal Seasonal Withdrawal 3/ Surface (AF)	Normal Seasonal Withdrawal 3/ Ground (AF)	Normal Seasonal Withdrawal 3/ Total (AF)
HOLBROOK (HOL)								
Holbrook	740	1,930	320	340	660	-	2,590	2,590
Joseph City 4/ 13/	1,500	1,570	620	910	1,530	900	2,200	3,100
Hay Hollow	1,610	3,790	460	1,540	2,000	-	2,200	5,790
Woodruff	400	870	300	470	800	500	1,170	1,670
Sub-Total	4,250	8,160	1,730	3,260	4,990	1,400	11,750	13,150
SNOWFLAKE (SNO)								
Snowflake-Taylor	2,240	3,770	4,520	3,010	7,530	8,300	3,000	11,300
Snowflake-Wells	2,270	4,110	1,210	2,740	3,950	-	8,060	8,060
Pinedale & Dry Lake	190	340	350	270	620	-	960	960
Sub-Total	4,700	8,220	6,080	6,020	12,100	8,300	12,020	20,320
OTHER WUA's								
Puerco-Zuni WUA	340	890	390	420	810	-	1,700	1,700
Tuba City WUA	250	200	30	300	330	530	-	530
San Francisco Peaks WUA	40	50	40	80	120	170	-	170
Chinle Valley WUA	190	570	1,230	820	2,050	2,620	-	2,620
Sub-Total	820	1,710	1,690	1,620	3,310	3,320	1,700	3,020
ARIZONA TOTALS	29,870					64,950	35,230	100,180

1/ Values as shown for native grass are "net applied," not irrigation requirement.
2/ Estimates of losses have not been made for wild flooding on native grass.
3/ These are net withdrawals; they do not include storage losses nor stream transmission losses.
4/ This area has a water deficiency in some years. The number of acres irrigated & crop yields varies with surface runoff. The values as shown for irrigated acres and irrigation requirement are for full water supply conditions. The estimated withdrawals are for normal or average conditions; thus, the data as shown in the table should not be used to compute irrigation efficiencies.
5/ About 120 acres in the Show Low area are dry-farmed at times. The losses as shown are based upon 480 acres.
6/ Only about 90 acres at Pinetop-Woodland have an adequate water supply under present conditions. The losses as shown are based upon 90 acres.
7/ Value shown is 50% of average annual yield. 8/ Rough estimate of 4.0 AF/AC/year.
9/ Average seasonal dependable supply. 10/ Value determined from gage records on Lyman Canal, 29-year average.
11/ The value shown is annual, not seasonal, withdrawal.
12/ Rough estimate of 5.0 AF/AC/year.
13/ Available supplies at Joseph City can provide adequate irrigation for about 750 acres; estimate of losses and the irrigation requirement are based upon 750 acres.

Table 1-1A: Existing Conditions
Irrigation Water Use Data by Water Use Area
Little Colorado River Basin, New Mexico Portion

Water Use Are Irrigated Area	Irrigated Acres (AF)	Irrigation Requirement 1/ (AF)	Normal Losses: Off-Farm Conveyance (AF)	Normal Losses: OnFarm (AF)	Normal Losses: Total Losses (AF)	Normal Seasonal Withdrawal: Surface (AF)	Normal Seasonal Withdrawal: Ground (AF)	Total (AF)
ZUNI (ZUN)								
Zuni	1,400	2,140	2,300	2,140	4,440	6,580	0	6,500
Ramah	550	840	800	1,030	1,830	2,670	0	2,670
Nicoll's Lake	170	220	120	210	330	550	0	550
Page	0 2/	0	0	0	0	0	0	0
Sub-Total	2,120	3,200	3,220	3,380	6,600	9,800	0	9,800
CARRIZO WASH (CAR)								
Mangas Springs	100	100 5/	70	180	250	340	10	350
UPPER PUERCO (UPR)								
Navajo, Western Part McKinley Co (Red Lake)	300 3/	460	390	460	850	1,310	0	1,310
NEW MEXICO TOTALS	2,520 4/	3,760	3,680	4,020	7,700	11,450	10	11,460

1/ Crop irrigation water requirements during growing season.
2/ Approximately 200 acres of cropland can be irrigated, not irrigated during base year.
3/ Approximately 600 acres of cropland can be irrigated.
4/ Estimated 1975 irrigated acreage. Total irrigated cropland in New Mexico is 4,950 acres.
5/ Reduced weighted CIR due to late season water shortage.

New Mexico

Off-farm storage facilities and conveyance systems within the New Mexico portion of the Basin are generally inadequate. Some storage facilities were constructed on creeks and rivers with sediment problems. The result has been to reduce storage capacities due to sedimentation of the reservoirs. Another problem is the fact that average watershed yield is not consistently adequate to provide sufficient irrigation water for all the cropland. There are years when storage reservoirs fill to spillway levels and overflow for varied lengths of time. There are more years when runoff is in very short supply. Also, most of the runoff occurs during March, April and May. Direct irrigation diversion is not possible throughout the irrigation season. Drainage areas are relatively small and normal precipitation patterns do not provide the necessary water supply to irrigate the total acreage available. Usually, watershed yields, available storage, or both, limit the amount of water that can be carried over from wet years to dry years. During dry years, much of the irrigated cropland is treated as dryland due to water shortages.

Conveyance systems are mostly earthen canals excavated along the edges of the valley, where side drainages create numerous problems. The valleys are usually long and narrow requiring long canals to supply water to all the irrigated cropland. This situation contributes to additional conveyance losses and other problems.

Ramah Land and Irrigation Company: There are two main problems with the Ramah Irrigation Project: the irrigation storage reservoir system and the distribution system. The Ramah Reservoir storage capacity appears adequate when related to the drainage area and an increase in capacity will not insure a permanent irrigation water supply for all irrigated cropland in the system. Past history and available records indicate a shortage of water yield to the reservoir. This is due to the small size of the contributing drainage area and weather patterns in this part of the State.

Another problem is the off-farm conveyance systems. The irrigated area is a valley with meandering natural channels. A long main canal is on each side of the valley. Side drainage flood flows interrupt or delay irrigation during the summer months by plugging ditches or breaking ditch banks. Also, some of the laterals, which carry irrigation flows to fields away from the main canals, are located on steep gradients. Flows are hard to control and they cause erosion.

The company is interested in improving its irrigation system and has requested assistance in the past. The organization is a complicated system which does not lend itself to an easy solution for cost sharing and/or grant funding. The cost of improving all phases of the irrigation system are excessive. Some improvements in the main conveyance system and in the main laterals will improve off-farm irrigation efficiencies and reduce maintenance problems. The total improvement needs for conveyance systems and other land treatment, by water use area, are shown in Table 1-2A.

ONFARM CONSERVATION LAND TREATMENT

Arizona

Significant conservation land treatment needs have been identified in this study. Soil erosion on irrigated land is not presently a problem in this river basin, and the needed treatment is designed to improve soil condition and irrigation efficiencies. Table 1-2 lists the existing needs by WUA.

Table 1-2 - Existing Conditions
Conservation Land Treatment and Off-Farm Conveyance System Improvements Needed
Little Colorado River Basin, Arizona Portion

Water Use Area	Total Irrigated Acres	NEEDS Conservation Cropping System	Crop Residue Mgmt.	Minimum Tillage	Pasture & Hayland Mgmt.	OnFarm 1/ Irrigation Systems	Irrigation Water Mgmt.	Off-Farm System Improvement
		(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Linear Ft.)
White Mountains (WHM)	6,630	840	840	840	5,710	4,670	4,470	208,120
Concho Area (CON)	2,130 2/	150	150	150	1,720	960	1,420	0
St. Johns Area (STJ)	4,820 2/	330	330	330	3,770	4,440	5,010	143,650
Canyon Diablo Area (CDI)	1,100	50	50	50	710	760	760	71,280
Holbrook Area (HOL)	4,250	2,450	2,450	2,450	2,570	3,260	3,260	0
Snowflake Area (SNO)	4,700	910	910	910	3,740	4,700	4,700	14,470
Other WUA's 3/	820	270	270	270	550	810	820	69,840
TOTAL	24,450 2/	5,000	5,000	5,000	18,770	19,600	20,440	507,360

1/ Includes land leveling and smoothing, ditch lining, pipelines, water measuring devices, or other improvements.
2/ Does not include 5,420 acres of native grass.
3/ Includes: Puerco-Zuni Area (PRZ); Tuba City (TUB); San Francisco Peaks Area (SFP); and Chinle Valley (CHN).

Table 1-2A - Existing Conditions
Conservation Land Treatment and Off-Farm Conveyance System Improvements Needed
Little Colorado River Basin, New Mexico Portion

Water Use Area	Total Irrigated Acres	NEEDS Conservation Cropping System	Crop Residue Mgmt.	Minimum Tillage	Pasture & Hayland Mgmt.	OnFarm Irrigation Systems 2/	Irrigation Water Mgmt.	Off-farm System Improvement
	1/	(Acres)	(Acres)	(Acres)	(Acres)	(Acres) 3/	(Acres)	(Linear Ft.)
Zuni (ZUN)								
a) Zuni	1,400	1,400	640	640	360	2,600	1,400	90,600
b) Ramah	550	550	120	120	440	1,000	550	5,000
c) Nicoll's Lake	170	170	80	80	30	170	170	6,500
d) Page	0	0	0	0	0	0	200	4,000
Carrizo Wash (CAR)								
Mangas Springs	100	100	0	0	100	180	100	20,000
Upper Puerco (UPR)								
Navajo, Western Part McKinley Co.	300	300	0	0	300	600	0	16,900
TOTAL	2,520	2,520	840	840	1,230	4,550	2,420	143,000

1/ 1975 acreage.
2/ Includes land leveling and smoothing, ditch lining, pipelines, water measuring devices, or other improvements.
3/ Needs for Total Irrigated Cropland in the area, minus about 200 acres on which leveling is not needed.

New Mexico

Average onfarm irrigation efficiency in the New Mexico portion of the Basin is approximately 50 percent, which is not to unfavorable in comparison with efficiencies in other Western states with similar conditions. Small parcels, natural existing land slopes, soils, and irrigation methods being practiced contribute to low efficiencies. Crops grown are for domestic use with forage crops grown mostly for family-owned livestock. The incentive to increase irrigation efficiency is lacking due to the fact that: (1) high-yield cash crops are not grown; (2) water cost does not change with increased water use; and (3) water supply for all the irrigated cropland is uncertain. Table 1-2A lists the existing conservation land treatment needs that have been identified.

PROJECTED CONDITIONS

The projected conditions represents those that are expected to exist in the future if no new water resource or irrigation projects or programs, other than those authorized and funded, are implemented. Effects of on-going programs, such as the Soil Conservation Service's Conservation Operations Program and the Agricultural Stabilization and Conservation Service's Agricultural Conservation Program (ACP), are included in the projected conditions. It was also assumed that existing irrigation water rights would not be transferred or sold for any other purpose and that all irrigated cropland will be improved, although not all of it will be cropped every year due to water shortages. Any water savings due to increased efficiencies can be utilized to irrigate more acres within the existing systems or increase yields.

In projecting future water requirements for irrigation purposes in 1990, 2000, and 2020, it was assumed that all improvements will be in place, and good management practices will be followed. Some of the improvements and good management practices to help improve efficiencies are:

1. Complete land leveling on land that needs to be leveled.

2. Line or install pipelines in ditches with significant losses.

3. Build and maintain good border ridges on fields where the border method of irrigation is being used.

4. Install border widths and lengths to fit flows relative to crops grown and soil characteristics.

5. Check soil moisture to determine when to irrigate.

6. Record date of irrigation by fields to assist in determining moisture to be replaced.

7. Estimate irrigation water volume to refill the crop root zone by timing the stream size and making sure the area to be irrigated is covered.

8. For furrows and corrugations, use a "cutback" stream, especially needed on slopes for soils with low intake rates.

A "cutback" stream is an irrigation stream, reduced in size from the irrigation stream initially applied, for the purpose of reducing waste by surface runoff and deep percolation and to secure a more uniform depth of water application.

9. Consider the use of sprinkler irrigation if water quality is adequate and costs are not prohibitive.

10. For some truck crops and orchards, consider the use of drip irrigation.

ARIZONA

Table 1-3 shows the projected needs for off-farm storage and conveyance systems and for onfarm conservation land treatment. The needs are by time period and by water use area.

Table 1-4 shows the effects of the projected improvements on water losses and withdrawals. This data is shown by WUA and by time period. Overall irrigation efficiencies are projected to improve to 52 percent in 2020. For the same time periods, off-farm conveyance efficiencies are projected to improve to 72 percent and onfarm efficiencies are projected to improve to 73 percent.

NEW MEXICO

Table 1-3A shows the projected needs for off-farm conveyance systems and for onfarm conservation land treatment for the total irrigated cropland in New Mexico. The needs are by time period and by water use area. It is assumed that all of the irrigated cropland will be utilized by the projection years.

Table 1-4A shows the effects of the projected improvements on water losses and withdrawals. This data is shown by WUA and by time period. Base year irrigated acres were used in Table 1-4A for comparison purposes to show the projected effects expected when the projected improvements are in place.

In New Mexico, the overall irrigation efficiencies are projected to increase from 33 percent in 1975 to 60 percent in 2020. For the same time periods, off-farm conveyance system efficiencies are projected to increase from 68 percent to 75 percent and onfarm efficiencies are projected to increase from 48 percent to a potential of 80 percent.

ALTERNATIVE ACTIONS

The potential irrigation improvements considered in this study were formulated using USDA Procedures for Planning Water and Related Land Resources. These procedures identify two broad national objectives, National Economic Development (NED) and Environmental Quality (EQ). Alternative plans, directed toward satisfying each of these national objectives, were formulated. In general terms, the NED alternatives are directed toward increasing the output of goods and services. The EQ alternatives are directed toward enhancing environmental quality by the management, conservation, preservation, creation, restoration, or improvement of certain natural and cultural resources and ecological systems. A recommended alternative for each of the potential improvements was formulated after due consideration had been given to both the NED and EQ alternatives.

Table 1-3 - Projected Needs
Conservation Land Treatment and Off-Farm Conveyance System Improvements Needed
Little Colorado River Basin, Arizona Portion

Water Use Area	Projection Year	Total Irrigated Acres [1/]	NEEDS: Conservation Cropping System	Crop Residue Mgmt.	Minimum Tillage	Pasture & Hayland Mgmt.	OnFarm Irrigation Systems [3/]	Irrigation Water Mgmt.	Off-farm System Improvement
			(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Linear Ft.)
White Mountains (WHM)	1990	6,630	0	0	0	1,850	1,640	3,140	147,560
	2000	6,630	0	0	0	880	820	2,410	117,570
	2020	6,630	0	0	0	200	200	1,420	60,470
Concho Area (CON)	1990	2,130	0	0	0	660	800	980	0
	2000	2,130	0	0	0	350	710	770	0
	2020	2,130	0	0	0	100	560	470	0
St. Johns Area (STJ)	1990	4,820	0	0	0	620	2,040	1,990	106,650
	2000	4,820	0	0	0	190	1,220	1,080	86,650
	2020	4,820	0	0	0	0	420	320	49,650
Canyon Diablo Area (CDI)	1990	1,100	0	0	0	150	200	200	71,280
	2000	1,100	0	0	0	50	80	80	71,280
	2020	1,100	0	0	0	0	0	0	71,280
Holbrook Area (HOL)	1990	4,250	660	660	660	920	1,240	1,580	0
	2000	4,250	0	0	0	460	650	980	0
	2020	4,250	0	0	0	120	180	370	0
Snowflake Area (SNO)	1990	4,700	200	200	200	940	1,360	1,360	14,470
	2000	4,700	100	100	100	370	600	600	14,470
	2020	4,700	0	0	0	60	110	110	14,470
Other WUA's [2/]	1990	820	0	0	0	130	290	290	24,400
	2000	820	0	0	0	50	150	150	18,300
	2020	820	0	0	0	0	0	0	12,200
TOTALS	1990	24,450	860	860	860	5,270	7,570	9,540	364,360
	2000	24,450	100	100	100	2,350	4,230	6,070	308,270
	2020	24,450	0	0	0	480	1,470	2,690	208,070

1/ Does not include 5,420 acres of native grass.
2/ Puerco-Zuni Area (PRZ) ; Tuba City (TUB); San Francisco Peaks Area (SFP); and Chinle Valley (CHN).
3/ Includes land leveling and smoothing, ditch lining, pipelines, water measuring devices, or other improvements.

Table 1-3A - Projected Needs
Conservation Land Treatment and Off-Farm Conveyance System Improvements
Little Colorado River Basin, New Mexico Portion

Water Use Area	Projection Year	Total Irrigated Acres	NEEDS Conservation Cropping System	Crop Residue Mgmt.	Minimum Tillage	Pasture & Hayland Mgmt.	OnFarm Irrigation Systems	Irrigation Water Mgmt.	Off-farm System Improvement
		1/	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Linear Ft.)
Zuni (ZUN)	1990	4,170	2,520	1,300	1,300	1,220	1,220	2,520	49,500
	2000	4,170	3,520	1,870	1,870	1,650	1,750	3,520	55,600
	2020	4,170	3,520	1,870	1,870	1,650	1,000	3,520	1,000
Carrizo Wash (CAR)	1990	180	180	40	40	140	40	100	5,000
	2000	180	180	40	40	140	80	180	10,000
	2020	180	180	40	40	140	60	180	5,000
Upper Puerco (UPR)	1990	300	300	150	150	150	300	300	16,900
	2000	600	600	300	300	300	200	500	0
	2020	600	600	300	300	300	100	600	0
TOTALS	1990	4,650	3,000	1,490	1,490	1,510	1,560	2,920	71,400
	2000	4,950	4,300	2,210	2,210	2,090	2,030	4,200	65,600
	2020	4,950	4,300	2,210	2,210	2,090	1,160	4,300	6,000

1/ Total irrigated cropland in the WUA. See Table 1-4A for base year acreage.

Table 1-4 - Projected Effects 1/
By Conveyance System Improvements and Conservation Land Treatment
Little Colorado River Basin, Arizona Portion

Water Use Area	Projection Year	Irrigated Acres	Irrigation Requirement	Off-Farm Conveyance Losses	Farm	Total Losses	Normal Withdrawal	Potential Change in Withdrawal from Present Conditions
			(ac. ft.)	(ac. ft.)	(ac. ft.)	(ac. ft.)	(ac. ft.)	(ac. ft)
White Mountains (WHM)	1990	6,630	10,370	8,200	5,180	13,380	23,750	
	2000	6,630	10,370	6,970	4,830	11,800	22,170	-1,580
	2020	6,630	10,370	4,770	4,350	9,120	19,490	-4,260
Concho Area (CON)	1990	2,130	4,460	2,900	1,850	4,750	9,210	
	2000	2,130	4,460	2,900	1,710	4,610	9,070	- 140
	2020	2,130	4,460	2,900	1,520	4,420	8,880	- 330
St. Johns Area (STJ)	1990	4,820	8,260	6,470	3,470	9,940	18,200	
	2000	4,820	8,260	6,020	3,140	9,160	17,420	- 780
	2020	4,820	8,260	5,180	2,880	8,060	16,320	-1,880
Canyon Diablo Area (CDI)	1990	1,100	2,010	1,280	1,820	3,100	5,110	
	2000	1,100	2,010	1,280	1,400	2,680	4,690	- 420
	2020	1,100	2,010	1,280	1,220	2,500	4,510	- 600
Holbrook Area (HOL)	1990	4,250	8,160	1,730	3,260	4,990	13,150	
	2000	4,250	8,160	1,730	2,830	4,560	12,720	- 430
	2020	4,250	8,160	1,730	2,390	4,120	12,280	- 870
Snowflake Area (SNO)	1990	4,700	8,220	6,080	6,020	12,100	20,320	
	2000	4,700	8,220	6,080	4,070	10,150	18,370	-1,950
	2020	4,700	8,220	6,080	2,740	8,820	17,040	-3,280
Other WUA's 2/	1990	820	1,710	1,690	1,620	3,310	5,020	
	2000	820	1,710	1,500	1,390	2,890	4,600	- 420
	2020	820	1,710	1,310	1,160	2,470	4,180	- 840
TOTALS	1990	24,450	43,190	28,350	23,220	51,570	94,760	
	2000	24,450	43,190	26,480	19,370	45,850	89,040	- 5,720
	2020	24,450	43,190	23,250	16,260	39,510	82,700	-12,060

1/ Does not include 5,420 acreas of native grass, therefore the values for irrigated acres, consumptive irrigation requirement, and withdrawals are different from those shown in Table 1-1.

2/ Includes: Puerco-Zuni Area (PRZ); Tuba City (TUB); San Francisco Peaks (SFP); and Chinle Valley (CHN).

Table 1-4A - Projected Effects 1/
By Conveyance System Improvements and Conservation Land Treatment
Little Colorado River Basin, New Mexico Portion

Water Use Area	Projection Year	Irrigated Acres	Irrigation Requirement	Off-Farm Conveyance Losses	OnFarm	Total Losses	Normal Withdrawal	Potential Change in Withdrawal from Present Conditions
		2/	(ac. ft.) 3/	(ac. ft.)	(ac. ft.)	(ac. ft.)	(ac. ft.)	(ac. ft.)
Zuni (ZUN)	1990	2,120	3,200	2,370	2,500	4,960	8,160	
	2000	2,120	3,200	1,440	1,450	2,890	6,090	- 2,070
	2020	2,120	3,200	1,420	800	2,220	5,420	- 2,740
Carrizo Wash (CAR)	1990	100	100	60	150	210	310	
	2000	100	100	60	80	140	240	- 70
	2020	100	100	50	30	80	180	- 130
Upper Puerco (UPR)	1990	300	460	100	200	390	850	
	2000	300	460	100	170	270	730	- 120
	2020	300	400	100	110	210	670	- 180
TOTALS	1990	2,520	3,760	2,530	1,330	5,560	9,320	
	2000	2,520	3,760	1,600	1,700	3,300	7,060	- 2,260
	2020	2,520	3,760	1,570	940	2,510	6,270	- 3,050

1/ All numbers are rounded to the nearest 10.
2/ Base year irrigated acreage. Additional acreage irrigated when water supply is available. See Table 1-3A for total acreage.
3/ Normal seasonal consumptive use minus effective precipitation.

OPPORTUNITIES FOR USDA PROGRAMS

Tables 1-3 and 1-4 in the Projected Conditions section, show that most of the problems and needs associated with irrigated agriculture in the Little Colorado River Basin will be met by ongoing conservation programs. Consequently, there does not appear to be a need to accelerate the ongoing USDA conservation programs associated with irrigation. There are three areas in Arizona; West Taylor, Springerville, and Pinetop-Woodland that have potential for development as Resource Conservation and Development (RC&D) Project Measures or as PL-566 (The Watershed Protection and Flood Prevention Act) Projects. A discussion of each project follows.

WEST TAYLOR

The West Taylor project area is located in southcentral Navajo County, Arizona in the town of Taylor. This potential project is within the Snowflake (SNO) WUA.

The Show Low-Silver Creek Water Conservation and Power District supplies irrigation water to approximately 101 acres of land at Taylor that is used for truck crops, small grains and pastures. There is ample water to satisfy the irrigation requirements of the crops; however, the existing conveyance system is antiquated, operation and maintenance expenses are very high, and the open ditch is a health and safety hazard. Three children have lost their lives in the existing open ditch within the past 35 years.

An RC&D measure plan has been prepared for this potential project. The sponsors selected an alternative that consists of installing approximately 14,470 feet of PVC pipeline and associated outlet structure, measuring meters, trash cleaners, valves, etc. Installation cost of these works of improvement, including administration costs, is estimated at $124,700. Average annual monetary benefits are estimated at $10,100.

SPRINGERVILLE

The Springerville project is located in southeastern Apache County, Arizona, at Springerville and Eagar. This potential project is within the White Mountains (WHM) WUA.

The Springerville Water Rights and Ditch Company supplies irrigation water to approximately 63 acres of land that is used for truck crops, orchards, hay, pasture and residential yards. The normal water supply is adequate to meet needs; however, the existing conveyance system is very inefficient and frequently the land operators are forced to use city water to irrigate their crops.

An RC&D measure plan has been prepared for this potential project. The sponsors selected an alternative that consists of installing approximately 11,800 feet of low head buried gravity flow irrigation pipeline, a screened inlet structure, appropriate outlet structures, and in-line valves and water control structures. Installation cost of these works of improvement, including administration costs, is estimated at $63,200. Average annual monetary benefits are estimate at $9,500.

PINETOP-WOODLAND

The Pinetop-Woodland project is located in southeastern Navajo County, Arizona, in, and adjacent to, the small rural community of Pinetop. This potential project is within the White Mountains (WHM) WUA.

The Pinetop-Woodland Irrigation Company supplies irrigation water to approximately 190 acres of land that is used for production of truck crops, orchards, small grain, hay and pasture.

The existing conveyance system is very inefficient. Most of the land does not receive adequate irrigation water because of transmission losses.

The recommended alternative for this area consists of installing approximately 20,825 feet of PVC pipeline with appropriate inlet and outlet structures, valves, and water control structures. Installation cost of these works of improvement, including administration costs, is estimated at $177,800. Average annual benefits are estimated at $24,500.

IMPLEMENTATION

The RC&D program to provide cost sharing and technical assistance appears to be the best way to install the three needed projects. If funding for this program is not available in the future, the possibility of obtaining assistance through the Watershed Protection and Flood Prevention Act (PL-566) should be explored.

IMPACTS OF USDA PROGRAMS

The three proposed irrigation projects in the Arizona portion of the Basin were evaluated as potential RC&D Measures and will produce measurable impacts. It is proposed that all three of these potential measures be installed prior to the first projection year, 1990.

The Springerville and Pinetop-Woodland projects are located in the White Mountains WUA (WHM); the West Taylor project is located in the Snowflake WUA (SNO). Installation of the projects would reduce conveyance systems losses and reduce withdrawals by about 526 acre feet and 296 acre feet annually for the WHM and SNO water use areas respectively.

The combined impacts of the proposed actions are shown in Tables 1-5 through 1-8. Table 1-5 displays the impacts on national economic development; Table 1-6 shows the impacts on environmental quality; Table 1-7 shows the impact on the regional economy; and Table 1-8 shows the impacts on social well-being. In all three proposed projects, the recommended plans maximize national economic development and also emphasize environmental quality. Consequently, a display showing tradeoffs between various alternatives was not developed.

Table 1-5 - National Economic Development Account
Recommended Irrigation Developments
Little Colorado River Basin, Arizona Portion

Components	Measures of Effects (Average Annual)1/	Components	Measures of Effects (Average Annual)1/
Beneficial Effects:		Adverse Effects:	
A. The value to users of increased outputs of goods and services:		A. The value of resources required for the three irrigation projects	
1. Irrigation	$ 31,500	1. Irrigation pipelines, inlet structures, control devices, etc.	
2. Reduced O&M	11,900	a. Project Construction	$ 24,300
3. Utilization of unemployed and underemployed labor resources for project installation	1,500	b. Project OM&R	600
		2. Project administration	2,700
		3. Associated costs	800
Total Beneficial Effects	44,900	Total Adverse Effects	28,400
		Net Beneficial Effects	16,500

1/ 50 years @ 7 1/8 percent interest, rounded to nearest $100.

Table 1-6 - Environmental Quality Account
Recommended Irrigation Developments
Little Colorado River Basin, Arizona Portion

Component	Measure of Effects
Beneficial and Adverse Effects	
A. Areas of natural beauty	1. Eliminate unsightly conditions associated with open earthen irrigation ditches in and around urban areas. 2. Eliminate those ditch areas that are conducive to disposal of refuse. 3. Improve the visual quality of the landscape by eliminating the open ditches, thereby giving the land-scape a more natural appearance.
B. Quality considerations of water, air, and land resources.	1. Slightly reduce the amount of dust in the air by eliminating many maintenance operations. 2. Reduce the possibility of plugged culverts. Plugged culverts have frequently resulted in flooding of roads and adjacent lands. 3. Temporary increase in dust during construction. 4. Eliminate airborne smoke caused by burning of ditch banks. 5. Reduce power consumption of wells that apply supplemental irrigation water. 6. Temporary increase in erosion hazard during construction period. 7. Temporary increase in noise, dust, and exhaust fumes during project construction.
C. Biological resources of selected ecosystems.	1. Eliminate weedy growth along the banks of existing ditches. 2. Eliminate ponding water and reduce mosquito-breeding habitat. 3. Reduce the amount of insecticide used for vector control. 4. Reduce weed and seed production along irrigation ditches. 5. Eliminate the existing wildlife habitats in, and directly associ-ted with, the open ditches. 6. Reduce pesticide exposure hazard to people and livestock.
D. Irreversible and irretrievable commitments	1. Labor, materials, and energy for construction of the projects.

Table 1-7 - Regional Development Account
Recommended Irrigation Developments
Little Colorado River Basin, Arizona Portion

Components	Measures of Effects: State of Arizona (Average Annual Dollars) 1/	Measures of Effects: Rest of Nation (Average Annual Dollars) 1/
Income:		
Beneficial Effects:		
A. The value of increased output of goods and services to users residing in the region:		
1. Irrigation	$ 31,500	$ 0
2. Reduced O&M	11,900	0
3. Utilization of unemployed and underemployed labor resources for project installation	1,500	0
4. Additional net income accruing to the region from project installation	400	-400
Total Beneficial Effects	45,300	-400

Components	Measures of Effects: State of Arizona (Average Annual Dollars) 1/	Measures of Effects: Rest of Nation (Average Annual Dollars) 1/
Income:		
Adverse Effects:		
A. The value of resources contributed to achieve the outputs:		
1. Three recommended single purpose irrigation projects.		
A. Project installation	$ 11,300	$ 13,000
B. Project OM&R	600	0
2. Project administration	200	2,500
3. Associated Costs	800	0
Total Adverse Effects	12,900	15,500
Net Beneficial Effects	32,400	-15,900

1/ 50 years @ 7 1/8 percent interest, rounded to nearest $100.

Table 1-7 - Regional Development Account (continued) 1/
Recommended Irrigation Developments
Little Colorado River Basin, Arizona Portion

Components	Measures of Effects: State of Arizona	Measures of Effects: Rest of Nation	Components	Measures of Effects: State of Arizona	Measures of Effects: Rest of Nation
Employment:			Employment:		
Beneficial Effects:			Adverse Effects:		
B. Increase in the number and types of jobs			B. Decrease in the number and types of jobs		
1. Employment in project construction	2.6 man years of semi-skilled labor and 1 man year skilled labor	0	1. Loss of employment from reduced O&M	.8 annual man years of semi-skilled employment	0
Total Beneficial Effects:	2.6 man years of semi-skilled labor and 1 man year skilled labor	0	Total Adverse Effects:	.8 annual man years of semi-skilled employment	
			Net Beneficial Effects	+2.6 man years of semi-skilled labor and +1 man year of skilled labor during construction of the projects. -.8 annual man years of semi-skilled labor used in O&M of the existing conveyance system.	

1/ Installation of the three proposed projects will have no effect on population distribution or the region's economic base and stability.

Table 1-8 - Social Well-Being Account
Recommended Irrigation Developments
Little Colorado River Basin, Arizona Portion

Components	Measures of Effects

Beneficial and Adverse Effects:

A. Real income distribution

1. Create regional income benefit distribution of $45,300 by income class as follows: 1/

Income Class (Dollars)	Percentage of Adjusted Gross Income in Class	Percentage Benefits in Class
<$3,000	36.5	36.5
$3,000 - $10,000	42.1	42.1
>$10,000	21.4	21.4

2. Local costs to be borne by region total $12,900 with distribution by income class as follows: 1/

Income Class (Dollars)	Percentage of Adjusted Gross Income in Class	Percentage Contributions in Class
<$3,000	36.5	36.5
$3,000 - $10,000	42.1	42.1
>$10,000	21.4	21.4

B. Life, health, and safety

1. Eliminate possibility of loss of life from children drowning in an open irrigation canal.
2. Eliminate breeding habitat of mosquitoes.
3. Eliminate fire hazard from weeds growing along the ditches and burning the ditch banks.
4. Reduce pesticide exposure hazard to people and livestock.

1/ County data for Apache County, Arizona 1970. This data is believed to be representative of the concerned areas. Specific area data not available.

IRRIGATION WATER QUALITY

GENERAL

Surface and groundwater quality investigations were conducted toward the following objectives: (1) to define any significant problems resulting from the use of low quality water and determine where USDA programs can alleviate these problems; (2) to determine the extent that irrigated agriculture in a particular area of the Basin contributes salt loading to receiving waters, and (3) to determine any change in water quality over time.

DATA SOURCES

Information on the chemical characteristics of irrigation water in the Basin was obtained from a literature review of published data covering the period 1934-1978. The data was supplemented by interviews with persons knowledgeable about the area and by field surveys.

Surface Water Quality

Arizona: The primary data source for the chemical characteristics of surface water in Arizona were computer printouts from the U. S. Environmental Protection Agency's STORET Water Quality Data System (22). Summary printouts showing mean values were provided by EPA Region IX. Raw data, showing the results of individual lab tests for selected samples, were provided by the consulting firm of Dames & Moore, Phoenix, Arizona.

The STORET printouts contain water quality data as collected by four agencies; the Arizona Department of Health Services (ADHS), the U.S. Geological Survey (USGS), the U.S. Forest Service (USFS), and the U.S. Environmental Protection Agency (EPA).

The ADHS survey was conducted in July 1973 in the upper reaches of the Little Colorado River and its tributaries above Holbrook. This survey was of particular value in assessing the impact of irrigation on receiving water quality as it was conducted during the height of the irrigation period and included sampling points both upstream and downstream of most of the irrigated lands in the Basin. Data from 58 ADHS sampling stations were selected for evaluation.

The ADHS, in conjunction with EPA, USGS, and the Northern Arizona Council of Governments, 208 Program, conducted a special water quality survey (2) on the headwaters of the Little Colorado River in the area of Greer, Arizona. This survey, conducted in the summer of 1977, analyzed water from 16 different sites along the river in an attempt to isolate probable sources of bacteriological contamination. The data was examined but not used in this evaluation because the sampling sites are upstream of the irrigated lands. The data is of excellent value in establishing baseline water quality for the upper reaches of the Little Colorado River.

The USGS has been sampling the receiving waters of the Basin since 1969 (1). These are the only tests presently available on the river below Holbrook and on the Navajo Indian Reservation. Data from 78 USGS sampling stations were selected for evaluation.

The USFS has been sampling the waters of the Little Colorado drainage along the Mogollon Rim within national forest boundaries since 1968. STORET contains data from 27 sampling stations within the Basin. This USFS data was briefly examined but not used in the evaluation.

The EPA conducted a special "lake survey" of several lakes and streams in the White Mountain area in late 1974 and through 1975. STORET contains data from 20 sampling stations.

The Arizona Game and Fish Department (AGFD) has 12 water quality stations in the Basin (1). Two are located in the upper headwaters near Greer and ten are located on the Show Low Creek drainage. These AGFD tests were not evaluated.

In addition to STORET printouts, other data published by the USGS and the University of Arizona, Agricultural Experiment Station (AES) were reviewed. This includes AES Bulletin 225, November 1949 (30), Bulletin 223, September 1964 (29), and Bulletin 256 (6). These bulletins contain only limited test data on surface water, however, the data that was available was valuable in the evaluation of long-term changes in water quality.

New Mexico: The data source for the chemical characteristics of surface water in New Mexico is a report prepared for the New Mexico Bureau of Mines and Mineral Resources by W. K. Summers (16).

Ground Water Quality

The primary data sources on the quality of groundwater were the above mentioned AES Bulletins and numerous USGS publications covering the period 1937-1976.

Since 1934, the USGS has conducted a program of groundwater studies. Data was reported in the USGS Water Supply Paper report format. In 1974, the USGS in cooperation with the Arizona Department of Water Resources, revised the system of collecting and reporting groundwater data in Arizona. Under the revised system, selected areas are studied in detail each year and data published in a map format. Raw data, including chemical analysis, is entered into computer storage.

With reference to the present study, USDA contracted with the USGS to develope a map entitled, "Availabitlity of Groundwater for Irrigation, Municipal or Industrial Use in the Little Colorado River Basin." This map, in additon to showing approximate well yields in selected parts of the Basin, also gives an indication of the Total Dissolved Solids (TDS) concentrations of the groundwater. Copies of this map(s) are located in Section 5 of this Appendix.

FACTORS DETERMINING WATER QUALITY FOR IRRIGATION

The suitability of a water for irrigation is determined by the amount and kind of suspended and dissolved substances in the water. The evaluation of water quality is a very complex and expanding science. A vast amount of research has been done on this subject and the effort continues. Perhaps the primary research in the past has been in assessing the impacts of salinity on crop yields and permeability and also how individual constituents and combinations of constituents affect yields and permeability. A lot of research has also been done on individual constituents such as boron, chloride, sulfate, nitrate, the trace elements, and recently on pesticides.

The data on crop tolerance levels as shown in this report was drawn from several sources. The primary reference in regard to salinity and permeability is U. S. Department of Agriculture Handbook 60 (14) published in 1954 by the U. S. Salinity Laboratory. This handbook classifies water quality in terms of an Irrigation Water Class which involves two variables; the Sodium-Absorption Ration (SAR) and the Electrical Conductivity (EC). The SAR is related to the content of sodium, calcium, and magnesium. More information on Irrigation Water Class and the SAR is provided later in this report.

Ayers and Westcot (4) have recently completed a report for the Food and Agriculture Organization of the United Nations that pulls much of the research of irrigation water quality together into one volume. They use an Adjusted Sodium Absorption Ratio (adj. SAR) to add an analysis of carbonate and bicarbonate to the analysis of sodium, calcium and magnesium as defined by the SAR.

This writing uses the SAR and Irrigation Water Class (See Table 1-13 and not the adj. SAR because all of the samples selected for evaluation did not have an analysis of carbonate and bicarbonate. Chemical analysis for these constituents is necessary to compute the adj. SAR, and also to analyze for bicarbonate alone as proposed by Eaton (6) and others. This writing does not include an analysis of bicarbonate for the water in the Little Colorado River Basin, however, no problems are evident.

Ayers and Westcot also group the varied facets of irrigation water quality into four problem areas: (1) Salinity, (2) Permeability, (3) Toxicity (4) Miscellaneous. These groupings are selected for presentation and discussion in this writing.

Salinity

Water, as it comes in contact with rocks and soil, dissolves the salts that occur in these materials. A salinity problem may occur if the total quantity of salts in the irrigation water is high enough that salts accumulate in the crop root zone to the extent that yields are affected. Excessive quantities of soluble salts create a condition where the crop has difficulty in extracting water from the salty soil solution. Ayers and Westcot (4) report that a plant takes most of its water from the upper part of the root zone and management of this zone is critical. It may be as important as providing adequate leaching to prevent salt accumulation in the total root zone.

Salts lose their identity when dissolved in water by separating into ions. It is customary to report and use irrigation water analysis in terms of ions rather than in terms of salts. There are two common methods of reporting on the sum of the ions in a water sample. One method is to use the Total Dissolved Solids (TDS) as determined by laboratory analysis. The TDS is the sum of major ionic constituents in the water sample (calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chloride, nitrate and fluoride). The other method is to use the Electrical Conductivity (EC), which in this report is reported in millimhos cm ($ECX10^3$) as used by Ayers and Westcot (4).

Tolerance levels for salinity of irrigation water are reported on by several authorities. It is often difficult to classify waters on the basis of TDS alone because the combination of salts which occur are as important as the total amount present. This writing uses the Irrigation Water Class to evaluate the salinity of irrigation water in the Basin. The impacts of salinity on crop yields is not specifically addressed. Ayers and Westcot (4) present information on yield decreases to be expected for certain crops due to salinity considering both the Electrical Conductivity and the saturation extract of soil and the Electrical Conductivity of the irrigation water, however, their procedure generally requires site specific information on soils and crops that are beyond the scope and intent of this report.

Permeability

Ayers and Westcot (4) state the following on permeability problems:

"A permeability problem related to water quality occurs when the rate of water infiltration into and through the soil is reduced by the effect of specific salts or lack of salts in the water to such an extent that the crop is not adequately supplied with water and yield is reduced. The poor soil permeability makes it more difficult to supply the crop with water and may greatly add to cropping difficulties through crusting of seed beds, waterlogging of surface soil and accompanying disease, salinity, weed, oxygen and nutritional problems. It is evaluated firstly, from total salts in the water since low salt water can result in poor soil permeability due to the tremendous capacity of pure water to dissolve and remove calcium and other solubles in the soil..."

Permeability problems are commonly expressed in terms of the total salts (TDS or EC) and either a comparison of the relative content of sodium to calcium and magnesium in the water (SAR method) or by considering sodium, calcium, magnesium, carbonates and bicarbonates (adj. SAR method, Ayers & Westcot).

This writing uses the SAR method which is discussed in the following section on Irrigation Water Class.

Irrigation Water Class

The Irrigation Water Class is usually determined by two variables, the Sodium-Absorption Ratio (SAR) and the Electrical Conductivity (EC). The SAR is related to the sodium content one expects to find in the soil if the water is used for irrigation. Since the physical properties of soils high in sodium are detrimental to plant growth, the SAR is a measure of the sodium hazard of an irrigation water. The SAR is calculated from the concentration of Na^{+}, Ca^{++} and Mg^{++} expressed in meg/l using the equation:

$$SAR = \frac{Na^{+}}{\frac{Ca^{++} + Mg^{++}}{2}}$$

The electrical conductivity, EC, of water is a measure of the total ions present in solution. Therefore, it is a measure of total salt content of water. High salt contents and high alkalinity (sodium content) in soils are detrimental to plant growth and reduced permeability. Thus irrigation water with high EC and/or high SAR will also be detrimental to plant growth. A classification system for irrigation waters, based on EC and SAR measurements was developed by the USDA (14) and is shown in Figure 1-1.

<u>C1-S1:</u> Low salinity-low sodium water: Waters in this class can be used with relative safety for irrigating any crop. It may be necessary to leach soils of low permeability occasionally if salt-sensitive plants are to be grown. There is little danger of developing harmful levels of exchangeable sodium from the use of waters of this class.

<u>C1-S2:</u> Low salinity-medium sodium water: Waters of this class can be used for irrigation if the salt which accumulates, through evaporation of water and water lost by transpiration, is leached from the root-zone. This should normally occur during irrigation.

If these waters are used on soils having high base exchange capacity dominated by sodium, the slow water penetration problem will be alleviated by the use of gypsum and the salts may then be leached from the soil quite readily.

C1-S3: Low salinity-high sodium water: Ordinarily there is a tendency for soils which are irrigated with waters of this class to disperse because of the high level of exchangeable sodium and thus reduce the rate of penetration of water into the soil. Treatment of such soils will consist of providing good drainage, the addition of soil amendments and organic matter, and the application of adequate water for leaching.

C1-S4: Low salinity-very high sodium water: Waters falling into this class may be considered likely to cause penetration problems on medium to fine-textured soils. Calcium from highly calcareous soils or from soils with gypsum present, may reduce the sodium hazard. If not naturally present, gypsum may be added. Organic matter should be used if available.

C2-S1: Medium salinity-low sodium water: Waters in this class may be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices of salinity control. Very little danger exists from the development of harmful levels of exchangeable sodium, but some sodium-sensitive crops such as stone-fruit trees and avocados may accumulate injurious levels of sodium.

C2-S2: Medium salinity-medium sodium water: These waters will present a sodium hazard when used on fine-textured soils having a high base-exchange capacity. Gypsum should be applied, followed by moderate leaching. On coarse-textured or organic soils of good permeability, this water may be used without special caution.

C2-S3: Medium salinity-high sodium water: This water, being high in sodium will produce harmful amounts of exchangeable sodium in the soil, requiring special soil management if crops are to be produced successfully. These practices include adequate drainage, high leaching, and organic matter additions. If the soil is not well supplied with gypsum, this amendment should be added to either the soil or the water. Chemical amendments may bring about the required condition in the soil but their use may not be feasible for low monetary value crops.

C2-S4: Medium salinity-very high sodium water: Very high sodium waters are seldom used for irrigation except in the low and medium salinity classes. Unless

calcium is available in the soil, it must be added. Good soil drainage is essential if waters in this class are to be used for irrigation. Waters in this class could not be used successfully except on very permeable soils or on those well supplied with calcium. If these conditions are not present, amendments may be used to supply the necessary calcium.

<u>C3-S1:</u> High salinity-low sodium water: This water should only be used on soils which can be leached easily. Salinity control must be practiced at all times. Only salt tolerant plants should be grown.

<u>C3-S2:</u> High salinity-medium sodium water: This water should be used only on those soils which have good drainage. Gypsum should be added to the soil or water, if it is not already present in the soil, to facilitate leaching. Only plants having a good salt tolerance should be grown.

<u>C3-S3:</u> High salinity-high sodium water: This water should be used only on soils having unrestricted drainage where special management for salinity control may be practiced. Because of the marginal nature of this water, special practices should include good drainage, frequent leaching and organic matter additions. Gypsiferous soils may not be adversely affected by the use of water of this quality but others may develop harmful levels of exchangeable sodium. The cost of chemical amendments could be prohibitive in extreme conditions.

<u>C3-S4:</u> High salinity-very high sodium water: Because of the high salt content of this water, it should be used only on soils having unrestricted drainage, for use by crops with good salt tolerance. Unfortunately, amendments may not be practical with waters of very high salinity.

<u>C4-S1:</u> Very high salinity-low sodium water: This water is generally considered to be poor quality for irrigation but it may be used if all other conditions are favorable. Specifically, drainage must be adequate, additional water must be applied for leaching and only crops of the highest salt tolerance used. There is little likelihood that this class of water will create an exchangeable sodium problem.

<u>C4-S2:</u> Very high salinity-medium sodium water: The very high salinity of this water permits occasional use and only then under favorable soil and plant conditions. An exchangeable sodium problem might develop in a soil irrigated with this water if the soil is fine-textured or otherwise poorly drained. Gypsum will reduce the sodium hazard. Only plants of high salt tolerance should be grown if water of this quality must be used.

C4-S3: Very high salinity-high sodium water: Because of the excessively high salt content of this water it is not recommended for use except under very special conditions. If used at all, the soil must be permeable and well drained. Water must be applied in considerable excess to provide for leaching, and only the most salt tolerant crops should be used. With respect to the high sodium content, this water will contribute to the development of unfavorable conditions in the soil which in turn will require the standard treatment for the prevention and cure of high-sodium soil conditions.

C4-S4: Very high salinity-very high sodium water: This water is undesirable for irrigation with respect to both salinity and alkalinity. If used at all, it should be used very freely to leach the salt from the soil. Calcium from any source, whether dissolved from the soil or applied as an amendment, may improve the water to the point where it may have limited use, thus calcium amendments may improve conditions where waters belonging in classes C1-S3 and C1-S4 may have provisional use as irrigation waters.

Toxicity

A toxicity problem occurs when certain constituents in the water are taken up by the crop and accumulate in amounts that result in a reduced yield (4). The specific ions considered in this report are boron. chloride, sulfates and some of the trace elements.

Boron: Boron, like some other nutrients, is essential for normal plant growth in low concentrations, but is toxic if present in high concentrations. The boron tolerance depends upon the type of crop. Several researchers have developed tolerance levels for boron, usually grouping the crops into three classes: tolerant, semitolerant, and sensitive (see Table 1-9).

TABLE 1-9 - Boron Limits
Reference (29)

	Permissible Limits of Boron (PPM) 1/
Sensitive Crops	0.33 to 1.25
Semitolerant Crops	0.67 to 2.50
Tolerant Crops	1.00 to 3.75

Citrus is the most sensitive crop, but there is no citrus in the Basin. With the exception of apples, most of the crops grown fall into the semitolerant and tolerant classes.

The water quality analysis data that is available indicates that boron levels in the waters of the Basin do not constitute a hazard to the crops grown.

1/ The concentration of parameters in this report is reported in both mg/l and ppm, which are synonymous for the most part.

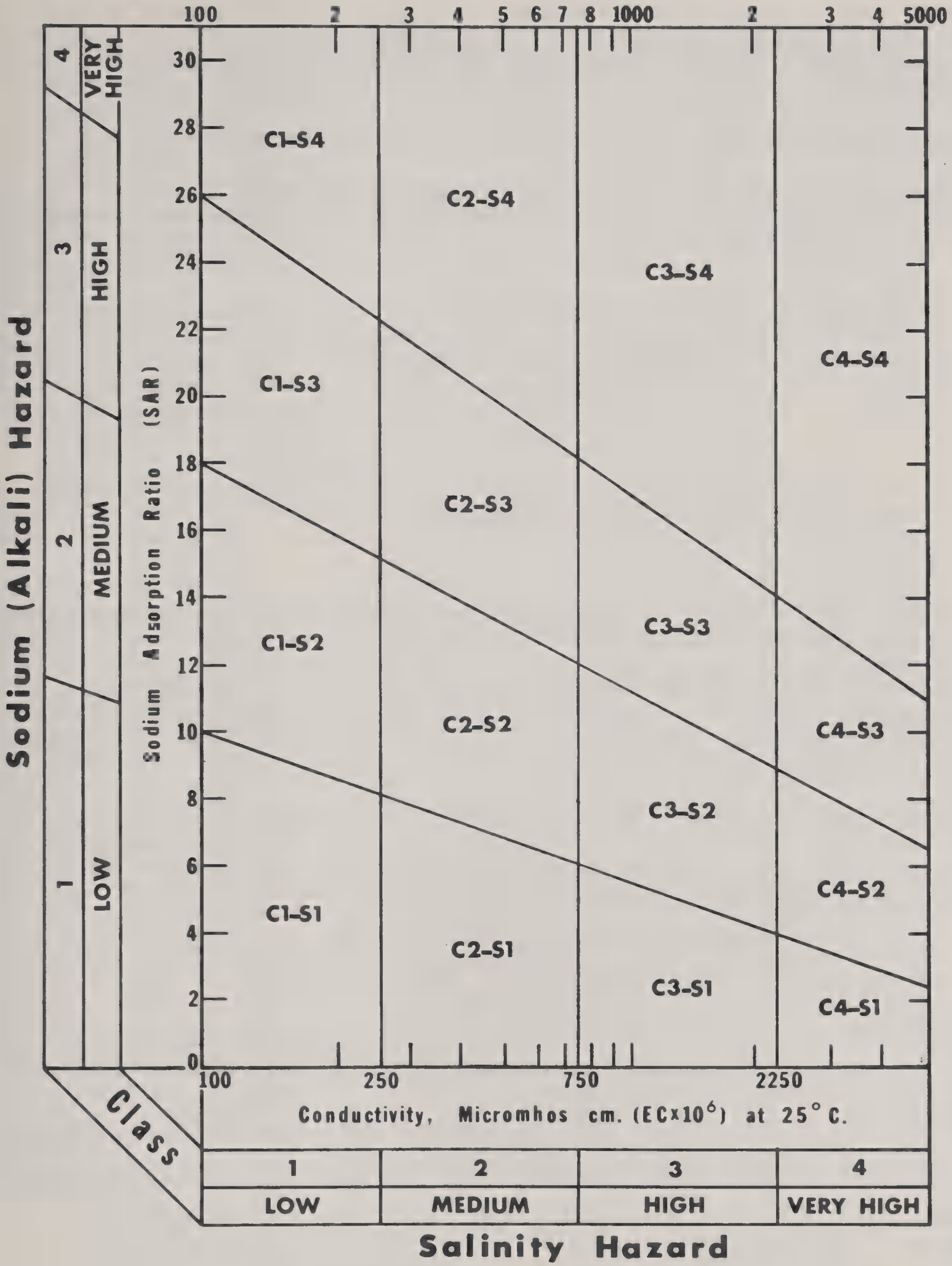


Diagram for the classification of irrigation waters.

Figure 1-1

Reference 14

Chloride and Sulfates: Dutt and McCreary (6) report that chloride is a trouble-some anion in irrigation water. Plants that have been shown to exhibit chloride toxicity include: alfalfa, fruit trees, and potatoes. All of these are grown in the Basin.

Sulfate, while less toxic than chlorides, may precipitate calcium in plants (6).

The permissible range of chlorides and sulfates as prepared by W. T. McGeorge and L. A. Richards (30) are shown below. Both parameters were considered in the analysis for this report.

TABLE 1-10
Classification of Waters with Respect to Chloride and Sulfate Content
Reference (30)

Concentration p.p.m.		Quality
0-175 chlorides;	0-350 sulfates	Good
179-290 " ;	350-600 "	Fair
over 290 " ;	over 600 "	Poor

Trace Elements: Dutt and McCreary (6) report on the toxic effect on some plants from nickel, copper, cobalt, zinc, and lead. The Economics and Statistics Service (7) has proposed limits for these elements plus aluminum, arsenic, beryllium, cadmium, chromium, lithium, manganese, molybdenum, selenium, and vanadium. The Environmental Studies Board, National Academy of Science, National Academy of Engineering (1972) has proposed limits for all of the above elements plus iron and fluoride (8).

Chemical analysis for all of the trace elements is practically non-existent. Some data is available for arsenic, cadmium, copper, lead, nickel, and zinc. These elements were considered where test data was available, using the limits as shown by the Environmental Studies Board (see Table 1-11).

TABLE 1-11 - Trace Element Tolerances
For Irrigation Water
Reference (8)

Element	For Waters Used Continuously on all soils (mg/l)	For use up to 20 years on fine textured soils of pH 6.0 to 8.5 (mg/l)
Arsenic	0.1	2.0
Cadmium	0.01	0.0
Copper	0.2	5.0
Lead	5.0	10.0
Nickel	0.2	2.0
Zinc	2.0	10.0

Miscellaneous: There are various other problems related to irrigation water quality. Ayers and Westcot (4) state that these include excessive vegetative growth, lodging and delayed crop maturity resulting from excessive nitrogen in the water supply, white deposits on fruit or leaves due to sprinkler irrigation with high bicarbonate water and suspected abnormalities indicated by an unusual pH of the water.

This report discusses two parameters in the miscellaneous category; Nitrate (expressed as NO_3) and pesticides. There is insufficient data to analyze bicarbonate and some of the other constituents.

Nitrate (NO_3): Excessive nitrate in irrigation waters tends to cause excessive foliar growth in some crops (6). If a water containing 10 p.p.m. of nitrogen in the form of nitrate, each acre-foot of water applied will add the equivalent of 128 pounds of ammonium sulfate to each acre of soil (30). Permissable limits of nitrate for irrigation water are open to question. The element was considered in this analysis assuming a nitrate limit of 10 p.p.m.

Pesticides: Pesticides are chemical compounds used to control undesirable plants, animals, and insects. Major categories of pesticides include insecticides, nematocides, miticides, fungicides, herbicides, and rodenticides.

Crop injury has been observed when the level of herbicides in irrigation water exceeds certain limits. The Economics and Statistics Service (7) has established herbicide crop injury thresholds in irrigation water for 12 herbicides.

The USGS participates in the Pesticide Program, a network of regularly sampled water-quality stations where monthly samples are collected to determine the concentrations and distribution of pesticides in streams. Beginning in water year 1976, USGS has analyzed pesticide concentrations at four stations within the Basin; Little Colorado River above Lyman Lake (09384000), Show Low Creek near Lakeside (09390500), Little Colorado River at Greer (09383400) and Little Colorado River at Cameron (09401200).

USGS (28) has specifically analyzed for the presence of 25 different pesticides at each of the four sampling stations. Analyses were conducted on both the water and bottom mud. No pesticides were detected in any of the water samples at either of the stations. Minor concentrations of Diazinon (.2 ug/kg) were detected in the bottom mud at Station 09383400, Little Colorado River at Greer. This station is upstream of the irrigated lands in the Basin. The presence of DDE (2.21 ug/kg) and Dieldrin (0.0315 ug/kg) was detected in the bottom mud at Station 09401200, Little Colorado River at Cameron.

Summary of Parameters Selected for Evaluation

The water quality parameters used in the evaluations for this report are shown in Table 1-12.

Table 1-12
Summary of Parameters Selected for Evaluation

Parameter		Evaluation Method
Water Quality Indicators		
Flow	(cfs)	
Temperature	(^{o}F)	
pH	(SD)	
Turbidity	(JTU)	
Irrigation Problem		
Salinity	EC (water)	Irrigation Water Class
Permeability		Irrigation Water Class
EC (water)		
SAR		
Toxicity		
Boron	(B)	See Table 1-9
Chloride	(Cl)	See Table 1-10
Sulfate	(SO_4)	See Table 1-10
Trace Elements		See Table 1-11
Arsenic	(As)	
Cadmium	(Cd)	
Copper	(Cu)	
Lead	(Pb)	
Nickel	(Ni)	
Zinc	(Zn)	
Miscellaneous		
Nitrate	(NO_3)	10 mg/1
Pesticides		See Narrative

STATE WATER QUALITY STANDARDS

Arizona

The Arizona Water Quality Standards for Surface Waters as adopted by the Arizona Water Quality Control Council lists agriculture, which includes irrigation, as a "primary beneficial use" for all surface waters in the Little Colorado River Basin with the exception of Cholla Lake (a power plant cooling pond), which is listed as an "incidental beneficial use" (3). Water quality standards for ground water have not been established in the Basin.

The Council has estabished water quality standard for agricultural use on two parameters; the fecal coliform content and boron (see below).

a. Bacteriological Quality. The fecal coliform content shall not exceed a geometric mean of 1000/100 ml nor shall more than 10 percent of the samples during any 30-day period exceed 2000/100 ml, based on a minimum of five samples during such period.

b. Toxic – The concentration of boron shall not exceed 1.0 mg/1.

The standards also provide for exceptions. Those exceptions pertaining to agriculture are paraphrased below.

Exceptions

A. When the entire flow in a watercourse that would otherwise be dry at that time and place is effluent from wastewater treatment facility or agricultural irrigation return flow or combination thereof, the Council may, upon application, determine that all or part of such water standards do not apply where the Council finds that such entire flow does not present a substantial danger to the health of the public.

B. The standards shall not apply to the collection, return or drainage of agricultural irrigation return flow, excess or tailwaters to canals, laterals or other man made irrigation water delivery facilities within an agricultural irrigation system, or chemical maintenance of irrigation facilities with an irrigation system where agriculture is the only designated primary beneficial use, or physical or mechanical maintenance of irrigation facilities within an irrigation system. This exception shall in no case apply to natural or modified natural stream courses.

C. The standards shall not apply to registered aquatic herbicides and pesticides used by resource management agencies of state and federal government and including agricultural improvement districts, irrigation districts, irrigation waters delivery districts and flood control districts.

New Mexico

Surface water quality standards in New Mexico are established by the New Mexico Water Quality Control Commission. The Commission has not established standards for the Little Colorado River Basin as of this writing (10).

IRRIGATION WATER QUALITY BY IRRIGATED AREAS

Irrigation water quality refers to its suitability for use. The suitability of a particular water supply depends upon the types of crops, the type of soil, and management. A good quality water has the potential to allow maximum yield under good soil and water management practices. However, with poor quality water, soil and cropping problems can develop which will reduce yields unless special management practices are adopted.

This writing discusses the quality of water used for irrigation in the Basin. Data is presented both in narrative and tables; and arranged by individual irrigated area by county. The primary water quality factor discussed in the narrative is the Irrigation Water Class. Tables 1-13 and 1-13a present data on several parameters. The reader should refer back to the section titled "Factors Determining Water Quality for Irrigation" for a determination of the suitability of use and limitations imposed by the use of water at a particuilar irrigated area.

The data in Tables 1-13 and 1-13a is arranged by major irrigated areas within each county, covering a total period of record of 42 years (1934-1976). This data is also coded by the three letter identification code designating water use area. The water use areas are deleniated on the Irrigated Area Map. Data is presented for 82 stations in Arizona (46 surface water and 36 wells) and 6 irrigation reservoirs in New Mexico (See "Location of Water Quality Sampling Stations" Map following Table 1-14.)

There is a limited amount of data available on the concentration of the trace elements in the Basin. The trace element data that is available is shown in Table 1-14 for 9 stations (7 surface water and 2 wells). Because of the low permeability of the aquifers in the New Mexico portion of the Basin, there is little groundwater available for irrigation. Well yields are usually in the 1 to 10 gpm range with a few springs and wells going as high as 50 gpm. One well just outside the Basin near Tohatchi in McKinley County has a yield of 900 gpm, but is hot (36 degrees C) and 2500 feet deep. The SAR on the only sample tested was 29 with 98 percent sodium.

Apache County, Arizona

Springerville-Eagar (WHM): [1/] Sampling Stations Nos. 2 and 3 (See Table 1-13) were selected as representative of upstream and downstream conditions respectively for an analysis on the quality of irrigation water utilized by the Round Valley Water Users Association and the Springerville Street and Ditch Company. Tests at these stations were conducted by ADHS during the same period in July 1973.

Station No. 2 is representative of waters diverted by Big Ditch, Amity Ditch, and the Springerville town ditch. The downstream station No. 3, located above the junction with Nutrioso Creek, should be free from any distortions possibly injected by flows from Nutrioso Creek.

The tests show that the supply water is C1-S1. Levels of boron, chloride, sulfate, nitrate, and the trace elements are well below recommended limits.

A comparison of samples 2 and 3 shows a downstream increase in TDS, sodium, chloride, calcium, etc., however the downstream waters are still of excellent quality. The degree that agriculture contributes to these increases is not positively known.

St. Johns (STJ): [2/] Sample No. 7 is representative of waters supplied to the Lyman Water Company through the Lyman Canal. This water is classified as C1-S1 and C2-S1 at the point of diversion. There are no tests available on the quality of water as it leaves Lyman Canal, although there is undoubtedly some degradation resulting from supplemental water supplied by wells pumping into the canal and spring seeps. The water should be of better quality now than in past years due to lining of a major portion of the canal.

The St. Johns Irrigation Company receives water from Little Reservoir and by diversion from the Little Colorado River. The river diversion points are downstream of Salado Springs. These springs yield water from crevices in travertine, or calcareous tufa (25), and the water contains large quantities of dissolved mineral matter, mostly in the form of bicarbonates, sulphate, and chlorides of calcium and sodium (see Sample No. 8).

1/ White Mountain WUA
2/ St. Johns WUA

Little Reservoir receives water from two sources: (1) up to 400 AF per year from Lyman Canal and (2) diversion from the Little Colorado River below Salado Springs. Sample No. 10 (C4-S2) is representative of water supplied by direct diversion. The water is of poor quality, and its use contributes to a high water table condition and drainage problems in the valley area in and north of St. Johns. Irrigation water applied from the Lyman Canal, west of St. Johns, also contributes to the problem. The USGS, reported in 1964 that ".... farmers in the area report that before the irrigation ditches were built across higher parts of the Quaternary gravel, the gravel did not contain water. This fact suggests that water now present in the gravel in this area is seepage from the ditches and irrigated fields. Also, the quality of the water in the gravel is similar to that of the water put into the ditches and used for irrigation...." (24).

Concho (CON): 1/ The main source of irrigation water at Concho is Concho Spring. This spring flows from the contact of the basaltic lavas and underlying sedimentary rocks (25). The water is of excellent quality, with essentially no change over time.

Hunt (CON): 1/ Water for irrigation in the Hunt area is drawn from deep wells tapping Kaibab Limestone and Coconino Sandstone. The quality of water, (C2-S1, C3-S1) is very similar from both formations. USGS (24) reports that sandstone beds in the Kaibab are hydraulically connected with the Coconino Sandstone in most places. Water in the Coconino Sandstone becomes increasingly poorer in quality northeast from Hunt, and is generally unfit for irrigation (24).

Navajo County, Arizona

Pinetop-Woodland (WHM): 2/ Surface water for irrigation in the Pinetop and Woodland areas are by diversion from Billy Creek and Walnut Creek. Water from both sources is classified as C1-S1.

Lakeside (WHM): 2/ Water for irrigation within the town of Lakeside is obtained from Adair Springs. The springs are believed to come from the contact of vesicular lava and the underlying sedimentary rocks (25). There was no test data located for Adair Springs, however, data is available for Big Spring, which is located 3/4 mile west of Adair Springs. It is assumed that both springs are of similar quality (C1-S1).

Water is also obtained from Lakeside Coffer Dam, located on Walnut Creek, immediately downstream of Rainbow Lake, to irrigate lands northwest of Lakeside. This water is also classified as C1-S1.

Show Low (WHM): 2/ Sample No. 34 (Table 1-13) is representative of waters supplied to the Show Low Irrigation District from Show Low Creek. The water is classified as C1-S1, with little evidence of degradation between upstream and downstream sampling stations.

Snowflake-Taylor (SNO): 3/ Water supplied to the Show Low-Silver Creek Water Conservation and Power District by surface water diversion from Silver Creek is classified as C1-S1. Silver Springs supplies most of the water in Silver Creek. This is the largest spring in the area. It issues from lava, probably from the

1/ Concho WUA
2/ White Mountains WUA
3/ Snowflake WUA

contact of the basaltic rock and underlying sedimentary strata. A comparison of Sample Nos. 38 and 39 (1934 to 1972 - see Table 1-13) for Silver Springs shows no degradation over time. However, there is an increase in TDS along Silver Creek between the point of diversion near Shumway (Sample 42) and north of Snowflake (Sample 45).

This district also supplements the surface water diversions from Silver Creek by pumping from wells tapping the Silver Creek alluvium. There is no test data available on these wells, however the quality should be very similar to that of Silver Creek.

Irrigated areas around Taylor and Snowflake are pumping from the Coconino Sandstone. This water is of lesser quality (C2-S1) than the surface water from Silver Creek.

<u>Hay Hollow (HOL):</u> 1/ Wells in the Hay Hollow area are tapping the Coconino Sandstone. The water is classified as C2-S1 and very similar in quality to that in the Snowflake-Taylor Area. There is no indication of degradation in quality over time.

<u>Woodruff (HOL):</u> 1/ Water pumped from the Little Colorado River for irrigation at Woodruff is classified as C2-S1. At times it contains extremely high sediment loads. Irrigation wells in the area tapping the Coconino provide water of poorer quality (C3-S1), which are higher in salts than the surface water, and higher in salts than water from the Coconino in both the Hay Hollow and Snowflake-Taylor areas.

<u>Holbrook (HOL):</u> 1/ Wells that supply water for the irrigated lands south of the Little Colorado River at Holbrook are tapping the Little Colorado River alluvium and under lying Coconino aquifer (Coconino Sandstone and Kaibab Limestone). Water in the alluvium is hydraulically connected with water in the Coconino aquifer where the Moenkipi Formation is eroded away and the alluvium is in direct contact with the Coconino (23). Upward leakage of water from the Coconino is discharged into the alluvium and contributes to seeps into the river. This water is classified as C3-S1.

<u>Joseph City (HOL):</u> 1/ Water in this area, which is diverted from the Little Colorado River at Joseph City and pumped from wells tapping the Coconino aquifer is classified as C3-S2 and C4-S3 (see Table 1-13). This water is used successfully for the irrigation of salt-tolerant crops, primarily because of natural gypsum in the soil and leaching.

USGS (23) reports that north of Joseph City in the N 1/2 Sections 16 and 17, T18N, R19E, the quality of water in the Coconino aquifer is poor and marginal for irrigation use. USGS also has documented a deterioration in the quality of water during the pumping season. The lowering of water tables permits the salty water in the Coconino aquifer to move into areas of withdrawal and also permits the salty water in the lower part of the aquifer to move upward.

Catron County, New Mexico

<u>Mangas Springs (CAR):</u> 2/ The Mangas Springs irrigation area is supplied by spring fed reservoir and recently a newly developed irrigation well. There is no water quality data available on the springs or the well.

1/ Holbrook WUA
2/ Carrizo Wash WUA

McKinley County, New Mexico

Navajo (UPR): 1/ There is no cropland irrigation in the Navajo Reservation in the New Mexico portion of the Basin except Red Lake. Water quality is good except for sediment in the lake. Winds tend to create highly turbid water.

Ramah (ZUN): 2/ There is no water quality data on Ramah Irrigation reservoir. The water seems to be of suitable quality with no problems. Seeps and highwater table have created some wet areas with salt deposits but this is not a problem on cultivated areas.

Zuni Pueblo (ZUN): 2/ There are several irrigation reservoirs on the Zuni Reservation. Many of these are badly silted leaving little storage. The quality of water for irrigation is good.

Valencia County, New Mexico

Nicoll's Lake (ZUN): 2/ There is no water quality data available on Nicoll's Lake. There are no apparent problems on the irrigated lands.

Ojo Caliente (ZUN): 2/ This reservoir is in the Zuni Reservation in Valencia County. The water is high in salts.

Page (ZUN): 2/ Page was irrigated from a well in the past. There is no data available on the water quality.

WATER QUALITY SUMMARY

The surface waters used for irrigation in the Basin are generally of excellent quality. The quality of the streams that flow over the basaltic rocks in the upper reaches is closely similar to that from the major springs. Dissolved-solid concentrations range from about 60 to 150 mg/l. There is a slight deterioration in quality as the streams leave the basaltic rocks and flow over the sedimentary formations.

Poor quality surface water is currently used for irrigation at three areas; St. Johns (Apache County, Arizona), Woodruff and Joseph City (Navajo County, Arizona).

At St. Johns, the continued use of salty water by diversion from the Little Colorado River downstream of Salado Springs contributes to a high water table and drainage problem in the alluvium north of St. Johns. The problem is compounded by canal seepage from the unlined portions of Lyman Canal and percolation of applied irrigation waters through Quaternary gravels west of the town. Waters that accumulate in the alluvium of St. Johns cannot free drain. Heavy siltation has filled the main channel of the Little Colorado River. In many places the river course has been obliterated and barely discernible from the surrounding ground.

At Woodruff, surface water is pumped from the Little Colorado River and supplemented by wells. The river water is of good quality, however, periodically sediment concentration is extremely high during the irrigation season.

At Joseph City, high TDS water is diverted from the Little Colorado River. The source of the high dissolved solid concentrations are upward seepage of poor quality groundwater into the alluvium from the Coconino aquifer plus natural accumulations from surface water inflows.

1/ Upper Puerco WUA
2/ Zuni WUA

The primary source of ground water utilized for irrigation in the Basin are wells tapping the Coconino aquifer (Coconino Sandstone and Kaibab Limestone). The main area of recharge of this aquifer is in the southern part of the Basin along the north slopes of the White Mountains.

Ground water in the Coconino aquifer moves northward from the areas of recharge, generally becoming increasingly higher in TDS as it moves further away from the mountains.

In Apache County, the quality of water in the Coconino aquifer varies with location, but in general, the water southwest of a line through Hunt and St. Johns is suitable for irrigation. Northeast of this line the water is generally unfit for irrigation (24).

In Navajo County, the water southwest of a line through Joseph City and the southern boundary of the Petrified Forest National Park is suitable for irrigation. North of this line the water becomes increasingly high in TDS with a dominance of sodium and chloride and is generally unsuited for irrigation. Joseph City is right on the boundary of this line, with samples from wells north of Joseph City showing TDS concentration of over 3,000 ppm.

The levels of boron, chloride, sulfate and nitrate in the waters of the Basin are generally within acceptable tolerances, the exception being water from some wells in the Joseph City area that contain high concentrations of chloride.

Information on the concentrations of trace elements in the water of the Basin is limited, however, the data available indicates nontoxic concentrations (See Table 1-14).

There is no evidence of long term deterioration in water quality, either to surface or ground water supplies (See Table 1-13). One possible exception, reported by USGS (23) is at Joseph City where analyses of water from wells north of town show a deterioration in quality during the pumping season and from year to year.

The irrigated lands in the Basin do not contribute to any significant degree to salinity loading in the main stem of the Colorado River.

The degree that irrigated agriculture contributes to pesticide concentrations in the Little Colorado River cannot be positively stated due to the shortage of data, however, tests conducted to date indicate that the surface waters in the Basin are free of pesticides.

TABLE 1-13

WATER QUALITY PARAMETERS - IRRIGATION

LITTLE COLORADO RIVER BASIN, ARIZONA PORTION

(Mean Values)

No.	Description	SURFACE WATER Location Latitude	Longitude	WELL DATA Location* Sect. Tn. Rn.	Depth to Water (Ft)	Probable Aquifer	DATA SOURCE Agency	Agency No.	Reference No.	Date(s) Months/Year	Flow (cfs)	Temp (°F)	PH	Turbidity (JTU)	EC**	TDS (PPM)	Sodium (Na)(mg/1)	Calcium (Ca)(mg/1)	Magnesium (Mg)(mg/1)	S.A.R.	Irrigation Water class	Boron (B)(mg/1)	Chloride (Cl)(mg/1)	Sulfate (SO$_4$)(mg/1)	Nitrate (NO$_3$)(mg/1)
	Apache County																								
	Springerville-Eager																								
1.	Little Colorado at Greer	34-01-00	109-27-24				USGS	09383400	28	5-9/76	21.0	57.1	7.9	3.8	.064	58	4.1	6.1	1.9	.4	C1-S1	.288	2.7	4.9	-
2.	Little Colorado at AZ 273	36-06-12	109-20-48				ADHS	LC 022	22	7/73		66.9	7.75	8.5	.110	87	4.5	13.5	5.5	.35	C1-S1		1.0	8.0	2.5
3.	Little Colorado above Nutrioso Cr.	34-08-43	109-17-26				ADHS	LC 025	22	7/73	[illegible].5	65.1	8.3	1.5	.250	188	16.0	34.0	9.0	.63	C1-S1		3.0	9.0	1.0
4.	Little Colorado below Nutrioso Cr.	Sect. 17,T9N,R29E					AES	8366	6	10/66		65.8	7.75		.5	325±	20.0	34.0	17.0	.70	C2-S1	0	12.0	20.0	
5.	Little Colorado above Lyman	34-19-50	109-21-18				USGS	09384000	28	5-9/76	1[illegible].0	77.9	8.2	15.0	.498	310	39.0	45.8	20.8	1.2	C2-S1	.1	12.9	20.8	-
	St. Johns																								
6.	Lyman Lake						AES	SHL30428	29	4/58					.4	261	35.0	31.0			C2-S1		8.0	24.0	2.0
7.	Little Colorado below Lyman Lake						ADHS	LC 032	22	7/73		64.4		110.0	.233	183	16.0	31.0	6.5	.68	C1-S1		5.5	28.5	2.5
8.	Salado Springs						USGS	S 48	25	12/33						2259		324.0	72.0		-		412.0	703.0	0.1
9.	Little Colorado below Salado Spr.	34-26-00	109-22-[illegible]				USGS		22	4-9/75	10.12	63.7	7.25		2.305	1605	292.5	187.5	49.5	4.89	C4-S2	.485	320.0	500.0	
10.	Little Reservoir Filler Ditch						AES	274		2/72			7.45	135.0	2.93	2138	374.0	230.0	64.0	5.7	C4-S2		408.0	630.0	4.5
11.	Little Colorado below St. Johns	34-32-30	109-22-10				USGS		22	11/75	10.46	35.6			2.6	1700	320.0	190.0	50.0	5.3	C4-S2	.600	350.0	550.0	
	Concho																								
12.	Concho Spring						USGS	S43	25	1/34						91		14.0	-		-		3.0	2.0	.86
13.	Concho Spring						USGS		26	/75					.172	112±			-		-				
	Hunt																								
14.	Steel Bridge Well			4-14-25		Coconino Sandstone	USGS	251	25	1/34						322		49	19		-		58	75	.1
15.	Well			28-14-26		Coconino Sandstone	USGS	254	25	11/33						343		44	15		-		87	36	0
16.	Well			18-14-26			AES	47806	30	11/45						441	100	30	8.0	4.18	C2-S1		72	63	
17.	Well			-14-25			AES	52072	30	5/48						441	76	53	4.0	2.71	C2-S1		84	50	
18.	Well			1-14-25			AES	61002	29	7/51					1.1	756	164	83	165.0	2.39	C3-S1		264	69	
19.	Well			12-14-25			AES	8703	6	6/67		65.8	7.9		.8	520±	122	51	16.0	3.82	C3-S1	.07	132	112	
20.	Well			21-14-26			AES	8706	6	6/67		65.8	7.9		.7	455±	138	38	11.0	5.09	C2-S1	.15	128	56	
21.	Well			12-14-25	30	Coconino	USGS		26	/74-75					1.96	1270±					-				
22.	Well			12-14-25	29	Coconino	USGS		26	/74-75					1.18	750±					-				
23.	Well			14-14-25	172	Coconino	USGS		26	/74-75					.60	390±					-				
	Navajo Indian Reservation																								
24.	Black Creek Near Lupton	35-27-09	109-07-33				USGS	09395900	22	/71-76	41.0	62.2	7.57		.54	348.0	59.0	45.0	9.5	2.06	C2-S1	.130	23.3	105	
25.	Puerco River Near Lupton	35-19-40	109-04-10				USGS	09395650	22	7/71-72	314.8	67.8	7.48		.689	439	91.3	45.2	7.5	3.38	C2-S1	1.1	19.0	175	
	Navajo County																								
	Pinetop-Woodland																								
26.	Pinetop Springs	Sect. 3,T8N,R23E					USGS	S16	25	1/34						80		16			-		1	2	.30
27.	Billy Creek below Fish & Game	34-07-30	109-55-30				ADHS	LC 036	22	7/73	10	64.9		2.25	.145	122	7.0	19.0	8.5	.33	C1-S1		2.5	7.5	1.00
28.	Walnut Creek below Pine Lake	34-06-46	109-55-53				ADHS	LC 039	22	7/73		79.3		2.25	.210	152	8.0	25.5	11.0	.26	C1-S1		4.5	9.0	1.00
29.	Walnut Creek above Woodland Res.	34-07-30	109-56-53				ADHS	LC 042	22	7/73	1.0	68.5		2.03	.220	152	7.5	38.5	7.5	.29	C1-S1		2.5	8.0	1.00

TABLE 1-13 CONTNIUED

WATER QUALITY PARAMETERS - IRRIGATION

(Mean Values)

No.	Description	SURFACE WATER Location Latitude	Longitude	WELL DATA Location* Sect. Tn.Rn.	Depth To Water (Ft)	Probable Aquifer	DATA SOURCE Agency	Agency No.	Reference No.	Date(s) Months/Year	Flow (cfs)	Temp (°F)	PH	Turbidity (JTU)	EC**	TDS (PPM)	Sodium (Na)(mg/l)	Calcium (Ca)(mg/l)	Magnesium (Mg)(mg/l)	S.A.R.	Irrigation Water Class	Boron (B)(mg/l)	Chloride (Cl)(mg/l)	Sulfate (SO4)(mg/l)	Nitrate (NO3)(mg.l)
	Navajo County (Continued)																								
	Lakeside																								
30.	Big Springs	Sect. 36,T9N,R22E					USGS		23	8/72	2.0	55.4	7.5		.210	134	7.0	23.0	6.8	0.3	C1-S1		2.0	6.0	<1.0
31.	Rainbow Lake	34-09-00	109-59-02				EPA	040902	22	3-10/75		49.9	9.12		.200						---				
32.	Walnut Creek below Lake of Woods	34-09-41	109-58-38				ADHS	LC 046	22	7/73	1.0	69.8		2.65	.195	113	6.5	27.8	7.0	.28	C1-S1		2.5	8.5	1.0
	Showlow																								
33.	Showlow Creek near Lakeside	34-10-46	109-59-14				USGS	09390500	28	5-9/76	5.6	62.4	8.64	10.6	.145	97	6.8	15.4	9.4	.34	C1-S1	.026	4.0	5.3	<1.0
34.	Showlow Creek below Showlow Lake	34-11-47	110-00-13				ADHS	LC 049	22	7/73		59.7		23.0	.092	90	3.7	10.3	7.7	.21	C1-S1		1.7	12.0	1.0
35.	Showlow Creek at U.S. 60	34-15-26	110-01-30				ADHS	LC 050	22	7/73		71.1		11.6	.193	130	5.7	29.0	8.7	.24	C1-S1		1.7	11.0	
36.	Showlow Creek below Sawmill	34-16-10.7	110-01-54				USFS	031061	22	9/69		70.0	8.10								---		35.0	10.0	
37.	Showlow Creek below Showlow	34-16-19	110-01-59				ADHS	LC 052	22	7/73		76.5		10.0	.201	150	8.5	28.8	8.5	.36	C1-S1		1.8	10.3	1.8
	Snowflake-Taylor																								
38.	Silver Creek Spring	Sect. 28,T11N,R23E					USGS	S 10	25	1/34						88		11.0			---		1.0	12.0	.30
39.	Silver Creek Spring	Sect. 20,T11N,R23E					USGS		23	6/72		60.8	7.6		.153	113	8.5	12.0	7.1	0.5	C1-S1		2.9	2.9	
40.	Love Lake Spring	Sect. 33,T12N,R22E					AES	260-W	7	8/55					.500	349	32.0	33.0	20.0	1.39	C2-S1		20.0	T	
41.	Silver Creek above Daggs	34-21-09	110-59-12				ADHS	LC 054	22	7/73		74.3		1.75	.140	93	9.5	16.5	6.5	.5	C1-S1		1.0	6.0	1.0
42.	Silver Creek below Daggs	34-21-51	110-00-02				ADHS	LC 055	22	7/73		73.9		55.0	.105	108	6.5	21.0	8.5	.3	C1-S1		1.0	8.0	
43.	Silver Creek at Shumway	34-24-21	110-04-13				ADHS	LC 056	22	7/73		71.1		17.7	.185	156	7.7	27.0	7.0	.34	C1-S1		1.0	8.7	1.0
44.	Silver Creek at Taylor	34-27-44	110-05-17				ADHS	LC 057	22	7/73		74.8		23.3	.276	173	13.7	39.0	9.7	.51	C2-S1		1.0	11.7	1.0
45.	Silver Creek N. Snowflake	34-31-48	110-04-38				ADHS	LC 059	22	7/73		76.6		43.3	.413	345	20.3	67.0	14.0	.59	C2-S1		6.0	24.0	
46.	Silver Creek N. Snowflake	34-31-41	110-04-47				USGS		22	5/74	2.5	64.4	8.0		.675		26.0	68.0	35.0	0.6	C2-S1	.07	12.0	42.0	
47.	Well			26-13-21		Coconino Sandstone	USGS	114	25	1/34						336		28.0					14.0	20.0	2.5
48.	Well			2-12-21		Moenkopi Sandstone	USGS	118	25	1/34						1127		174.0	56.0				262.0	140.0	246.0
49.	Well			24-12-21			AES	257-W	29	8/55						373	28.0	35.0	24.0	1.3	C2-S1		18.0	T	
50.	Well			25-13-21		Coconino Sandstone	USGS		23	1/72		59.0	7.3		0.328	214	13.0	30.0	16.0	.5	C2-S1	.04	7.9	33.0	
	Hay Hollow																								
51.	Well			34-15-23		Coconino Sandstone	USGS		21	9/50		63			.502	302		49.0	19.0	.8	C2-S1		34.0	92.0	0.3
52.	Well			34-15-23			AES	8008	6	6/66		72	8.0		.500	300	24.0	60.0	21.0	.8	C2-S1	.11	32.0	98.0	
53.	Well			27-15-23		Coconino & Kaibab	USGS		23	11/66			7.0		.598	358	35.0	65.0	14.0	1.0	C2-S1		43.0	138.0	
	Woodruff																								
54.	Little Colorado at Woodruff	34-46-58	110-02-37				USGS	09394500	22	5/71-74	3.48	64.9	8.14		.547	342	73.2	25.6	12.6	12.0	C2-S1	.140	34.0	91.8	
55.	Well			20-16-22		Coconino Sandstone	USGS	106	25	1/34						584		71.0	31.0				162.0	120.0	0
56.	Well			17-16-22			AES	62039	29	6/52					1.2	804	145.0	90.0	8.0	3.9	C3-S1		96.0	238.0	
57.	Well			17-16-22			AES	8013	6	6/66		72.1	7.6		.9	595	80.0	88.0	30.0		C3-S1	.19	90.0	172.0	
58.	Well			17-16-22			USGS		23	5/68			7.2		.981			84.0		2.8	C3-S1		91.0	177.0	

TABLE 1-13 CONTINUED

WATER QUALITY PARAMETERS - IRRIGATION

(Mean Values)

No.	Description	SURFACE WATER Location Latitude	Longitude	WELL DATA Location* Sect. Tn.Rn.	Depth To Water (Ft)	Probable Aquifer	DATA SOURCE Agency	Agency No.	Reference No.	Date (s) Months/Year	Flow (cfs)	Temp (°F)	PH	Turbidity (JTU)	EC**	TDS (PPM)	Sodium (Na)(mg/1)	Calcium (Ca)(mg/1)	Magnesium (Mg)(mg/1)	S.A.R.	Irrigation Water Class	Boron (B)(mg/1)	Chloride (Cl)(mg/1)	Sulfate (SO_4)(mg/1)	Nitrate (NO_3)(mg/1)
	Navajo County (Continued)																								
	Holbrook																								
59.	Well			8-17-20			AES	46196	30	8/44						480	69.0	49.0	21.0				108.0	72.0	
60.	Well			11-17-20			AES	48719	30	7/46						1392	230.0	130.0	66.0				385.0	332.0	
61.	Well			8-17-20			AES	258-W	29	6/55					.7	568	102.0	33.0	30.0	3.1	C2-S1		136.0	60.0	
62.	Well			11-17-20			AES	61083	29	8/51					2.2	1520	288.0	203.0	19.0	5.2	C3-S2		540.0	246.0	
63.	Well			6-17-20			USGS		23	7/68		62.6	7.4		.839	445		42.0	26.0	2.5	C3-S1		113.0	68	
64.	Well			8-17-20			USGS		23	9/72		62.6	7.7		.885	491	100.0	39.0	26.0	3.0	C3-S1		130.0	83.	.01
65.	Well			11-17-20			USGS		23	9/72		62.6	7.6		2.36	1610	170.0	150.0	130.0	2.5	C4-S1		270.0	740.0	2.8
	Joseph City																								
66.	tle Colorado near Holbrook	34-52-58	110-06-23				ADHS	LC060	22	7/73		75.2		65.0	1.06	887	165.0	84.0	26.0	4.03	C3-S1		234.0	222	
67.	Little Colorado at Holbrook	34-53-52	110-09-45				USGS	09397000	22	5/71-74	39.5	60.5	7.95		.932	664	135.5	36.2	13.8	7.18	C3-S2	.103	203.2	115.5	
68.	Little Colorado near Joseph City	34-54-04	110-15-17				USGS	09397300	22	/73-76	475.0	59.5	7.9		1.056	609	129.0	51.3	24.8	3.43	C3-S1	.170	175.7	118.7	7.5
69.	Little Colorado below Joseph City	34- 5-30	110-19-25				USGS		22		0.13	73.4	8.0		4.900	2750	680.0	190.0	100.0	9.90	C4-S3	.360	1200.0	460.0	
70.	Well			16-18-19			AES	49959	30	6/47						1899	345.0	315.0	10.0				850.0	167.0	
71.	Well			16-18-19	130		AES	49959	30	9/43						3550	621.0	600.0	19.0				1560.0	450.0	
72.	Well			16-18-19			AES	78183	29	5/61					3.6	2516	533.0	260.0	46.0	8.0	C4-S3		880.0	475.0	
73.	Well			17-18-19	70		AES	80012	29	?/62					3.8	2502	481.0	286.0	72.0	6.5	C4-S4		994.0	485.0	13.0
74.	Well			16-18-19	150		AES	8146	6	7/66		72.1	7.6		4.6		1000.0	88.0	44.0		C4-S4	.37	1580.0	210.0	
75.	Well			16-18-19	150		AES	8148	6	7/66		72.1	7.7		1.0		105.0	86.0	70.0		C3-S1	.08	160.0	200.0	
76.	Well			17-18-19			USGS		23	6/72		63.5	7.5		3.13	1730	530.0	63.0	34.0	13.0	C4-S3		780.0	180.0	
77.	Well			17-18-19			USGS		23	7/72			7.8		1.0	600	174.0	51.0	31.0	4.4	C2-S1		190.0	116.0	
	Winslow																								
78.	Chevlon Creek near Winslow	34-55-35	110-31-51				USGS	09398000	22	5-10/71		63.6	7.4		1.898	1072	327.4	43.0	25.1	7.9	C3-S2	.05	491.0	91.0	
79.	Jacks Canyon near Winslow	34-55-17	110-47-49				USGS	09399400	22	5-12/71		65.1	7.0		0.104	74	1.95	15.5	2.58	0.125	C1-S1				
	Coconino County																								
	Navajo Indian Reservation																								
80.	Moenkopi Wash at Moenkopi	36-06-18	111-12-04				USGS	09401260	22	7/76-77	62.6	63.5	7.98		1.53	1427	167.3	209.6	50.4	3.1	C3-S1	.131	18.9	357.5	
81.	Little Colorado at Cameron	35-52-40	111-24-40				USGS	09401200	28	2-9/76	E570	61.3	8.14	14,100	0.555	366	77.4	34.2	7.8	3.48	C2-S1	.112	33.8	128.2	0

* See "Location of Water Quality Sampling Stations" Map for locations of sample site.

** Millimhos cm $(ECX10^3)$

TABLE 1-13A
WATER QUALITY PARAMETERS - IRRIGATION
LITTLE COLORADO RIVER BASIN, NEW MEXICO PORTION
(Mean Values)

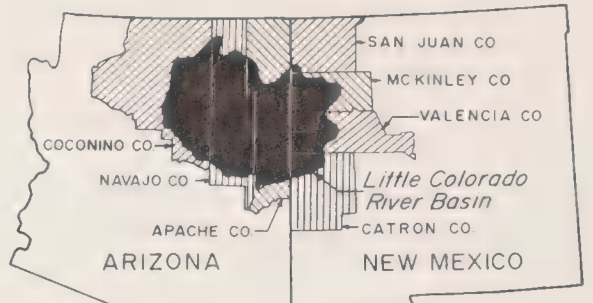
Description	Surface Water Location Sect. Tn. Rn.	Well Data Location* Depth Aquifer Sect. Tn. Rn.	Data Source Agency	Agency No.	Reference No.	Dates Mo/Year	Flow (cfs)	Temp (°F)	PH	Turbidity (JTU)	EC**	TDS PPM	Sodium (Na) (mg/l)	Calcium (Ca) (mg/l)	Magnesium (Mg) (mg/l)	Bicarbonates (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)	Boron (B) (mg/l)	Chloride (Cl) (mg/l)	Sulfate (SO_4) (mg/l)	Nitrate (NO_3) (mg/l)
McKinley County, N.M.																					
Black Rock Res.	17-10N-18W		BIA	68-Z-59	16	8/67			8.2		.400	232	20.0	16.2	8.5	108.01	Trace	0	13.5	89.3	0
Black Rock Res.				69-Z-12		7/68			8.7		.450	298	55.0	43.1	11.6	51.26	8.10	0.2	15.6	139.2	0.25
Pescado Reservoir	7-10N-16W		BIA	68-Z-58	16	8/67			8.5		.430	294	46.7	23.1	12.2	159.87	Trace	0	24.1	57.6	0
Pescado Reservour				69-Z-74		8/68			7.8		.536	330	15.2	39.1	9.7	125.70	Trace	Trace	5.3	78.3	0.60
Nutria Res. No. 2	12-11N-18W		BIA	68-Z-56	16	8/67			8.2		.360	258	41.8	18.0	12.8	62.99	18.21	Trace	27.7	55.7	0
Nutria Res. No. 2				68-Z-71		8/68			9.5		.380	246	40.5	19.0	12.2	3.66	59.72	Trace	18.4	59.6	Trace
Nutria Res. No. 4	33-12N-17W		BIA	68-E-62	16	8/67			8.7		.280	174	15.2	24.1	10.9	107.40	Trace	Trace	15.3	41.3	0.74
Nutria Res. No. 4				69-Z-72		8/68			9.3		.230	130	11.5	17.0	10.3	53.09	14.70	Trace	6.4	35.1	0.25
Nutria Diversion Res.	18-12N-16W		BIA	68-Z-57	16	8/67			8.1		.280	174	4.8	40.1	7.3	104.96	Trace	0	11.7	20.7	0
Nutria Diversion Res.				69-Z-70		8/68			7.6		.180	290	5.1	24.1	4.6	82.99	Trace	0.05	0.05	1.8	0.37
Valencia County, N.M.																					
Ojo Caliente Res.			BIA	68-E-61	16	8/67			8.0		.850	608	48.4	8.1	30.4	115.94	Trace	0	42.6	267.5	0
Ojo Caliente Res.				69-E-73		8/68			8.1		.990	738	56.6	85.2	39.5	107.40	6.00	Trace	40.8	364.1	Trace

* See "Location of Water Quality Sampling Stations" Map for locations of sample sites.
** Millimhos cm ($ECX10^3$)

TABLE 1-14

TRACE ELEMENTS
LITTLE COLORADO RIVER BASIN, ARIZONA PORTION
(mg/l)

No. (See Table 1-13	DESCRIPTION	DATA SOURCE Agency	Agency No.	Reference No.	Date(s) Month/Year	Arsenic (As) Mean	Max.	Cadmium (Cd) Mean	Max.	Copper (Cu) Mean	Max.	Lead (Pb) Mean	Max.	Nickel (Ni) Mean	Max.	Zinc (Zn) Mean	Max.
1.	Little Colorado at Greer	USGS	09383400	28	5-9/76	.0006	.001	<.01	<.01	.011	.017	<.1	<.1	–	–	.01	.02
–	Nutrioso Creek above Little Colorado	ADHS	LC 029	22	7/73	.01	.01	.01	.01	–	–	.05	.05	–	–	.05	.05
3.	Little Colorado above Nutrioso Creek	ADHS	LC 025	22	7/73	.01	.01	.01	.01	–	–	.05	.05	–	–	.05	.05
5.	Little Colorado above Lyman Lake	USGS	09384000	28	5-9/76	.0024	.004	.0008	.002	.008	.01	<.1	<.1	–	–	.014	.02
19.	Well at Hunt	AES	8703	6	6/67	–	–	–	.0006	–	.126	–	.0004	–	.0134	–	.037
20.	Well at Hunt	AES	8706	6	6/67	–	–	–	.0006	–	.23	–	.076	–	.0134		.072
33.	Showlow Creek near Lakeside	USGS	09390500	28	5-9/76	.0024	.005	–	.002	<.009	<.01	<.1	<.1	–	–	.006	<.01
–	Showlow Creek above Showlow Lake	ADHS	LC 048	22	/73-75	.01	.01	.01	.01	–	–	.05	.05	–	–	.05	.05
81.	Little Colorado at Cameron	USGS	09401200	28	2,4,8/76	–	.006	–	.002	–	.01	–	.006	–	–	–	.67



LOCATION MAP

SAMPLING STATIONS

Surface Water

Ground Water

Note: See tables for data on water samples.

LOCATION OF WATER QUALITY SAMPLING STATIONS

LITTLE COLORADO RIVER BASIN

ARIZONA AND NEW MEXICO

1979

10 0 10 20 MILES

SCALE 1:1,000,000

Source:
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series.
Thematic detail compiled by state staff.
U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

M7–EN–23833–5

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SECTION 2

MUNICIPAL AND INDUSTRIAL WATER SUPPLY

SECTION 2

Municipal and Industrial Water Supply

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MUNICIPAL AND INDUSTRIAL WATER SUPPLY

INTRODUCTION

The Little Colorado River Basin is a rapidly growing area in northeastern Arizona and northwestern New Mexico, (1950 population: 87,600, 1975 population: 162,200). The Basin's economy includes agriculture, lumbering, manufacturing, wholesale and retail trade, and government. Recreation has also played an important part in the Basin's economy in recent years. Some of the Basin's rapid growth is related to the increased use of its prime recreational areas.

Water, in a large part of the Basin, is a scarce resource; scarce in the sense that not everyone can use as much as he wants under the prevailing conditions. Competition for water is a fact. Tradeoffs must be considered seriously. In some cases restrictions on use may be required.

The major water use in the Basin is for agriculture, and accounts for more than 60 percent of the Basin's total water withdrawal. Most of this water is used for irrigation. Water used for industry is expanding. Water used for domestic purposes accounts for only a small percentage of the Basin's total water withdrawal. As the population continues to grow, this percentage will increase.

Of the estimated 162,200 population, over 65 percent reside in cities and towns. These communities are served by numerous municipal, corporate, or investor-owned water systems. The adequacy of these systems varies considerably, both with respect to total available water supply and to storage and distribution capacities.

Water furnished by the various water systems can be broken into four major categories of use (15)*: Domestic, Public, Commercial and Industrial. These are defined as follows, and are referred to in this paper as municipal and industrial uses:

1. Domestic - includes water required for households, lawn and garden irrigation, and home swimming pools;

2. Public - includes water required for public facilities (court houses, federal buildings, city offices, etc.), recreational use (parks, public swimming pools, etc.), firefighting and street cleaning;

3. Commercial - includes water used by restaurants, motels, garages, and similar establishments; and

4. Industrial - includes manufacturing processes such as those occurring in electronic plants, fabricating plants, and similar enterprises. For this paper, industrial use is limited to those industries attached to community water systems; industries with self-supplied systems are not included. Data for self-supplied systems are included in Section 5 of this Appendix.

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* Numbers in parentheses refer to references listed in back of this Section of the Appendix.

The size of community and type of industrial enterprises that use a particular water system influence the percentage of each category. In general, gallons-per-capita-day (gpcd) rates increase as the populations of communities increase because requirements for public, commercial, and industrial water uses expand as a city grows.

The purpose of this report is to identify those areas that have existing or projected municipal and industrial (M&I) water shortages, the amount of additional water needed, and possible ways to obtain the needed water. Also studied were storage and distribution systems for selected communities in the Basin and their adequacy to meet both present and future demands.

The adequacy of existing water supplies was determined by comparing present capacities with existing demands, where existing demands were based on estimated per capita use rates for the various communities. With reference to storage, a general "rule of thumb" states that recommended storage be equal to fire storage plus a one-day supply for domestic purposes. Fire storage was based on recommendations by the American Insurance Association and varies with respect to the community's population. (9). The one-day supply for domestic purposes was estimated at 200 gpcd. Judgement with respect to the adequacy of the distribution system was made on the stipulation that for fire fighting purposes, approved fire hydrants must be installed on minimum 6-inch mains.

Data for the study are presented by community, county, and water use area. In Arizona, the water use areas (with minor modifications) are those defined by the Arizona Department of Water Resources and the U.S. Geological Survey in their studies of the groundwater resources for the state. In New Mexico, surface water drainage boundaries define the water use areas, (see Water Use Areas Map, following Page 3-2, Section 3).

PRESENT WATER SUPPLY, STORAGE, AND DISTRIBUTION

Water supplies to meet M&I demands within the Basin are derived from three major sources. These are surface water reservoirs, springs, and pumped groundwater. Most of the demands are met through groundwater pumping both in Arizona and New Mexico. Only the City of Flagstaff is presently using surface water reservoirs as a major source for M&I purposes. St. Johns, in recent years, however, has used water from Lyman Reservoir and still holds approximately 100 shares in the Lyman Project. This water is now being used solely as a reserve for emergency situations.

Several communities in the Basin, including the cities of Flagstaff and St. Johns use water from developed springs. Also included in this list are the communities of Greer, Eagar, and Keams Canyon. Several small trailer parks and subdivisions located in the Show Low, Pinetop, and Lakeside areas, as well as many recreational sites in the Apache-Sitgreaves and Coconino National Forests, are dependent upon springs for their water supplies.

Storage and distribution systems were also investigated during this portion of the study. Data was obtained on 41 separate communities located within the Basin.

Several of the Arizona communities have two or more water supply and distribution systems. The Show Low, Pinetop, and Lakeside areas have numerous water systems. In the Show Low area alone, within a five-mile radius of the city, there are approximately 17 different water systems. There are 14 systems in or near Lakeside and six in the Pinetop area. Greer also has several water supply systems.

In general, these supply systems are small and serve a limited number of people. Better efficiency would be obtained is some of these systems could be combined under a single water district, so that available supplies could be used over a wider area and line sizes could be standardized.

General descriptions of the water supply, storage, and distribution systems for several of the communities located within the Basin are listed below. Data was not available for many of the smaller rural communities. Data also was inadequate for most of the communities located on Indian reservations. These include Greasewood, Kin-Li-Chee, Leupp, Moenkopi, Hotevilla, Low Mountain, New Oraibi, Pinon and Polacca listed in Tables 2-2, 2-3, and 2-4. Only the larger reservation and off-reservation communities had data available to adequately describe the present water supply systems (Table 2-1 shows pertinent facts about each community's water supply, Table 2-3 shows population data.)

A general discussion of the water quality is also included in the descriptions for the selected communities. Pertinent data with reference to water quality is given in Table 2-2. Environmental Protection Agency Standards (EPAS) are shown at the top of the table for comparison purposes.

For a complete discussion of EPAS, the reader is referred to the Safe Drinking Water Act of 1974 as amended by Public Law 95-190, dated November 16, 1977. The following is a brief summary of the act and some of its major provisions.

The Safe Drinking Water Act (SDWA) was enacted to ensure that the public drinking water is safe. Congress intended that the states should have the primary role in the implementation of the act. However, for thsoe areas where the states do not have civil jurisdiction needed to enforce the act, the EPA will have primary implementation role. This is the case for water supplies on Indian lands in Arizona, Nevada and California. Since the State's and EPA's standards are similar if not the same, the EPA standards have been referenced throughout this report. Some key terms and provisions of the act are as follows:

A. Public Water System: A public water system has 15 or more service connections or regularly serves an average of 25 or more persons daily for at least 60 days a year.

B. Community Public Water System: A community public water system serves a residential (year round) population. Thus, a community system is one in which the same people are drinking water from the same source over a long period of time. For example: cities, towns, mobile home communities.

C. Non-Community Public Water Systems: A non-community public water system serves intermittent users such as tourists. For example: campgrounds, rest stops, motels, restaurants. Thus, those that drink the water each day are probably different people and do not drink very much of the water.

D. Maximum Contaminant Level (MCL): MCL's are the maximum levels of contaminants permissible in the drinking water. The National Academy of Sciences has

TABLE 2-1: COMMUNITY WATER SUPPLY DATA, LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO

Location and Community	Water Use Area	Wells	Well Capacity	Average Consumption (1000)	Storage Capacity (1000)
		(No.)	(gpm)	(gpd)	(gal).
ARIZONA					
Apache Co., Arizona					
Ft. Defiance, Window Rock & St. Michaels 1/	CHN	18-25	490	560	-
Greasewood 1/	CHN	-	-	191	-
Kin-Li-Chee 1/	CHN	-	-	40	-
Chambers/Sanders	PRZ	18-20	-	99	90
Navajo	PRZ	1	25	18	0
Witch Well 1/	PRZ	-	-	10	-
St. Johns 2/	STJ	2	215 3/	210	1,600
Eagar 2/	WHM	3	262	156	71.5
Greer	WHM	1	-	32	108.5
Nutrioso	WHM	1	-	2	0
Springerville 2/	WHM	4	455	161	315
Vernon 1/	WHM	-	-	6	8.5
Concho	CON	2	65	64	255
Coconino Co., Arizona					
Leupp 1/	HOP	-	-	91	-
Flagstaff 2/	SFP	13	6,770 4/	3,551	102,000
Moenkopi	TUB	-	-	105	-
Tuba City	TUB	-	-	653	300
Navajo Co., Arizona					
Hotevilla 1/	BLM	1	61	90	-
Keams Canyon	BLM	2	150	21	600
Low Mountain 1/	BLM	-	-	25	-
New Oraibi 1/	BLM	2	110	60	-
Pinon 1/	BLM	-	-	52	-
Polacca 1/	BLM	-	-	50	-
Winslow	CDI	4	1,950	1,520	3,520
Heber 1/	CHV	2	-	67	330
Overgaard	CHV	3	650	79	170
Holbrook 2/	HOL	3	2,000	1,188	1,800
Joseph City	HOL	2	600	124	500
Woodruff 1/	HOL	1	-	40	12

TABLE 2-1: COMMUNITY WATER SUPPLY DATA,
LITTLE COLORADO RIVER BASIN,
ARIZONA AND NEW MEXICO
(CONTINUED)

Location and Community	Water Use Area	Wells	Well Capacity	Average Consumption (1000)	Storage Capacity (1000)
		(No.)	(gpm)	(gpd)	(gal)
Navajo Co., Arizona (cont)					
Shumway 1/	SNO	-	-	20	-
Snowflake	SNO	2	1,350	423	1,000
Taylor	SNO	2	1,050	147	426
Pinetop/Lakeside	WHM	15	-	870	2,080
Show Low	WHM	4	1,410	449	1,500
NEW MEXICO 5/					
Catron Co., New Mexico					
Quemado	CAR	2	35	10	15
McKinley Co., New Mexico					
Gallup	UPR	12	2,600	2,600	13,600
Gamerco	UPR	1	60	50	190
Zuni	ZUN	4	400	125	500

1/ Number of wells, well capacities, and/or storage capacities are unknown.
2/ Does not include data for spring developments or for new wells which have recently been installed in the respective communities. Also, new storage facilities have been added at Springerville, Holbrook, and Pinetop.
3/ Although not presently being used, an additional 90 gpm are available to St. Johns from Lyman Lake Reservoir.
4/ When both the Lake Mary Reservoir and spring developments located in the Inner Basin are producing at maximum capacity, an additional 4,160 gpm are available to the City of Flagstaff.
5/ From published data (4, 5, and 15) and updated by interviews with city officials or water supply owners.

TABLE 2-2: WATER QUALITY DATA FOR SELECTED COMMUNITIES
LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO

Community or Developed Area	Water Use Area	Arsenic (Mg/l)	Barium (Mg/l)	Cadmium (Mg/l)	Chromium (Mg/l)	Fluoride (Mg/l)	Lead (Mg/l)	Mercury (Mg/l)	Nitrate (As N) (Mg/l)	Selenium (Mg/l)	Silver (Mg/l)	Turbidity (TU)	TDS (PPM)	Total Hardness (PPM)	Iron (PPM)	pH
		INORGANIC CONTAMINANTS														
EPA STANDARDS (MCL)1/		0.05	1.0	0.01	0.05	1.4 to 2.4 2/	0.05	0.002	10	0.01	0.05	5	500	-	0.3	-
ARIZONA																
Apache County																
Ft. Defiance, Window Rock, St. Michael's	CHN	.005	0.3	.002	.017	-	.005	.0005	0.3	.005	.03	-	-	-	0.1	-
Greasewood	CHN	0.01	<0.4	T 3/	T	0.5	T	<.002	0.14	T	T	0.99	529	230	T	8.2
Kin-Li-Chee	CHN	T	0.42	T	T	0.13	T	<.002	0.28	T	T	0.62	382	258	T	8.3
Chambers/Sanders	PRZ	<.01	-	<.01	<.01	0.77	<.05	<.0005	8	<.01	<.01	<5	663	260	0.05	7.5
Navajo	PRZ	<.01	-	<.01	<.01	0.74	<.05	<.0005	3	<.01	<.01	<5	195	16	<.05	8.2
Witch Well	PRZ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
St. Johns	STJ	.005	1.00	.005	.010	0.25	.020	.0005	0.50	.005	.010	<5	1573	740	<.05	7.2
Eagar	WHM	.005	-	.005	.010	1.30	.020	.0005	-	.005	.010	-	425	-	-	-
Greer	WHM	<.01	-	<.01	<.01	0.21	<.05	<.0005	<1	<.01	<.01	<5	130	80	0.06	8.0
Nutrioso	WHM	<.01	-	<.01	<.01	0.27	<.05	<.0005	<1	<.01	<.01	<5	415	194	<.05	7.5
Springerville	WHM	<.01	-	<.01	<.01	0.62	<.05	<.0005	<1	<.01	<.01	<5	278	166	0.13	7.7
Vernon	WHM	<.01	-	<.01	<.01	0.08	<.05	<.0005	<1	<.01	<.01	<5	117	68	<.05	8.0
Concho (Area)	WHM	<.01	0.50	<.01	<.01	0.39	<.05	<.0005	<1	<.01	<.01	<5	236	156	<.05	-
Coconino County																
Leupp	HOP	.005	T	T	T	0.2	0.02	<.002	0.56	T	T	-	732	552	T	8.4
Flagstaff	SFP	.006	-	.005	.01	0.12	0.02	<.005	0.50	.005	.01	<5	312	308	0.17	7.9
Moenkopi	TUB	<.005	<0.2	<.002	<.005	0.2	<.005	<.0005	<0.3	<.005	<.03	-	240	131	<.05	7.9
Tuba City	TUB	.003	T	T	T	0.15	T	<.002	0.56	T	T	0.8	168	5	.02	9.5
Navajo County																
Hotevilla	BLM	.005	<0.2	<.002	<.005	0.2	<.005	<.0005	<0.3	<.005	<.03	-	180	3	<0.1	9.6
Keams Canyon	BLM	.012	<0.2	<.01	<.002	0.2	<.005	<.0005	<0.3	<.005	<.02	-	-	-	<0.1	-
Low Mountain	BLM	.003	T	T	T	3.8	T	<.002	T	T	T	0.4	1068	10	T	8.8
Oraibi (New)	BLM	.01	<0.2	<.002	<.005	0.2	<.005	<.0005	<0.3	<.005	0.04	-	-	-	<0.1	-
Pinon4/	BLM	.002	.15	T	T	0.30	T	<.002	0.25	T	T	17.3	545	333	.03	8.7
Polacca	BLM	.028	<0.2	<.002	<.005	0.5	<.005	<.0005	<0.3	<.005	<.03	-	1080	614	<0.1	7.5
Winslow	CDI	<.01	-	<.01	<.01	0.22	<.05	<.0005	<1	<.01	<.01	<5	412	320	0.1	8.8
Heber	CHV	<.01	-	<.01	<.01	0.14	<.05	<.0005	2	<.01	<.01	<5	200	216	< .05	-
Overgaard	CHV	-	-	-	-	-	-	-	-	-	-	-	246	-	-	-
Holbrook	HOL	-	-	-	-	0.40	-	-	-	-	-	-	559	-	0.36	-
Joseph City	HOL	.005	.55	.005	.010	.37	.020	.0005	3.5	.005	.010	-	579	-	-	-
Woodruff	HOL	-	-	-	-	0.31	-	-	0.5	-	-	-	-	-	-	-
Shumway	SNO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snowflake	SNO	<.01	-	<.01	<.01	0.25	<.05	<.0005	<1	<.01	<.01	<5	218	128	0.06	7.5
Taylor	SNO	.01	-	<.01	<.01	0.15	<.05	<.0005	4	<.01	<.01	<5	233	162	< .05	7.9
Lakeside	WHM	.01	0.23	.005	.010	0.23	0.020	.0010	0.73	.005	.020	<5	307	190	< .05	8.2
Pinetop	WHM	<.01	0.20	<.01	<.01	0.07	<.05	<.0005	<1	<.01	<.01	<5	145	98	< .05	7.7
Show Low & vicinity	WHM	.02	1.0	.005	.010	0.17	.033	.0005	0.50	.0008	.010	<5	309	262	-	8.3

TABLE 2-2: WATER QUALITY DATA FOR SELECTED COMMUNITIES
LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO
(continued)

Community or Developed Area	Water Use Area	INORGANIC CONTAMINANTS Arsenic (Mg/l)	Barium (Mg/l)	Cadmium (Mg/l)	Chromium (Mg/l)	Fluoride (Mg/l)	Lead (Mg/l)	Mercury (Mg/l)	Nitrate (As N) (Mg/l)	Selenium (Mg/l)	Silver (Mg/l)	Turbidity (TU)	TDS (PPM)	Total Hardness (PPM)	Iron (PPM)	pH
EPA STANDARDS (MCL)1/		0.05	1.0	0.01	0.05	1.4 to 2.4 2/	0.05	0.002	10	0.01	0.05	5	500	-	0.3	-
NEW MEXICO																
Catron County																
Quemado	CAR	0.01	-	<0.01	<0.01	0.98	0.01	-	1.2	0.005	-	1.3	485	286	0.27	8.2
McKinley County																
Gallup	UPR	<0.01	<0.44	<0.01	<0.03	0.41	<0.03	-	<0.15	<0.01	<0.05	1.1	829	66	0.51	8.4
Gamerco	UPR	0.10	<1.0	<0.01	<0.01	0.48	.018	-	<0.10	0.20	<0.05	1.0	700	25	<0.25	8.6
Zuni	ZUN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1/ MCL - Maximum Contaminant Level
2/ The MCL for fluoride is related to the annual average of the maximum daily air tempertature (see narrative).
3/ T - Trace
4/ Data is average of measurements at two separate wells.

identified five categories of contaminants: organics, inorganics, radionuclides, turbidity and microbiological. An MCL is usually expressed in milligrams per liter (mg/l) and contaminants are measured at the outlet (tap) of the water system, except for turbidity which is measured at the point of entry to the distribution system.

The MCL's are designed to prevent adverse health effects caused by drinking the same water over a long period of time. However, one inorganic contaminant (Nitrate), microbiological and turbidity can be related to rapid onset of health problems. Therefore, non-community as well as community water systems are required to meet these three MCL's.

The EPA Standards shown in Table 2-2 are referenced to the MCL's. Since no problems have been experienced in the Basin with respect to organics, these contaminants will not be discussed further in this report.

The MCL for fluorides is related to the annual average of the maximum daily air temperature:

Temperature °F	Level (mg/l)
53.7 and below	2.4
53.8 - 58.3	2.2
58.4 - 63.8	2.0
63.9 - 70.6	1.8
70.7 - 79.2	1.6
79.3 - 90.5	1.4

The MCL for turbidity in drinking water is one turbidity unit (TU) as determined by a one/day monthly average for surface supplies. Five or fewer TU's may be allowed if the higher turbidity does not do any of the following:

A. Interfere with disinfection.

B. Prevent maintenance of an effective disinfectant agent throughout the distribution.

C. Interfere with microbiological determinations.

The only known problem with microbiological contamination in the Basin occurred in the citizens-owned water system in Pinetop. This problem is discussed further under the description for this community.

With reference to radionuclides, only preliminary data is available. The available data, however, indicates that there is little problem with this contaminant in the Basin.

Other routine water chemistry data analyzed and shown in Table 2-2 includes: total dissolved solids (TDS), total hardness, iron and pH. These parameters give a general indication of the chemical quality of a community's water supply. This type of data was not available for some of the communities.

Apache County

Fort Defiance, Window Rock and St. Michaels: These three communities are located on the Navajo Reservation near the Arizon-New Mexico state line. They are in the Chinle Water Use Area. The communities are served by a single water distribution system which also serves the communities of Tse Bonita and Navajo in New Mexico. The system is owned and operated by the Navajo Tribal Utility Authority (NTUA). It consists of 18-25 individual wells of which about half are located in Arizona and half in New Mexico (Table 2-1). The total amount of storage available is unknown, but from existing data, it appears to be inadequate to serve the present population. Water quality data is given in Table 2-2. Additional water supply will be needed for the system as the population continues to grow. Several alternatives have been proposed. These include new wells and a proposed pipeline diversion from the Navajo Dam and Reservoir. However, the drilling of wells on most of the reservation is becoming more expensive and less reliable. A dam has also been proposed on Quartsite Canyon, a tributary to Bonito Creek, located north of Fort Defiance. Other possibilities for water storage are on Blue Canyon west of Fort Defiance, Bowl Canyon northeast of Navajo and on upper or lower Black Creek. An erosion control program to reduce runoff and promote groundwater recharge is a another possible alternative.

Chambers/Sanders: The communities of Chambers and Sanders are located along Interstate 40, near the central part of Apache County. They are located in the Puerco-Zuni Water Use Area.

The present water systems for these communities consist of approximately 18-20 individual wells scattered along the Puerco River floodplain between Chambers and Cedar Point. The largest users in the area are the Puerto School District and Arizona Park Estates, a trailer court. Data from the Arizona Department of Health Services indicate that these two systems use approximately 94 acre-feet per year. An additional 18 acre-feet per year are used by the Arizona Department of Tranaportation Entrance Station at Sanders. These systems will probably account for more than 90 percent of the total M&I water used in the area. The water supply system for the trailer court is not dependable, and the people have had to haul water in the recent past.

The only known storage facilities in the area are a 50,000 gallon storage tank at the Puerto Elementary School and a 40,000 gallon tank at the Arizona Park Estates. Neither system has sufficient storage for fire protection.

Water quality is fair, with slightly high total dissolved solids. Pertinent data for the Puerto School District well is used in Table 2-2 to illustrate the water quality for this area. This well is relatively high in nitrate, although it does not exceed EPA standards.

Navajo: Navajo is a small unincorporated community located along Interstate 40 about 40 miles northeast of Holbrook. It is in the Puerco-Zuni Water Use Area.

The present water system consists of one artesian well serving Spurlock Ranch and two small camping areas (Table 2-1). There are a few other individual wells scattered throughout the area.

Although there are only about 100 people in the immediate vicinity of Navajo, approximately 300 people haul water from the artesian well. There are no storage facilities and water pressure is very low near the end of the distribution line. Without storage, no fire protection is provided. The water is of excellent quality (Table 2-2).

Witch Well: Witch Well is a small community located in east-central Apache County at the junctiin of Highways 61 and 666. It is located in the Puerco-Zuni Water Use Area.

There is very little data available for this community. The estimated population in the area is 200. The only data obtained was from the Arizona Department of Health Services. The Department of Health Services denied the use of the water system developed for the Witch Well Mobile Estates, because of poor water quality. Water in this area is generally high in total dissolved solids. The present data indicates that some type of water supply improvement is needed in the area.

St. Johns: St. Johns lies at the junction of Highways 61 and 180. It is in the St. Johns Water Use Area.

There are three different sources of water available to the city. These include the Schuster and McIntosh Springs, Lyman Lake, and two new wells drilled in the Concho area (Table 2-1). The new wells were located near Concho because of the poor quality of groundwater (high TDS) found beneath St. Johns.

Lyman Lake is presently being used only as a reserve supply. Also, McIntosh Spring is not being used because the supply line is in need of repair and yield is not sufficient to justify the necessary repairs.

Storage facilities for St. Johns consist of two steel tanks with capacities of one million gallons and 600,000 gallons, respectively. These facilities are generally adequate to meet present needs for supply, but additional storage is needed to provide a reserve for fire protection. There is a need to replace some of the existing distribution lines, which are inadequate to meet the needs for fire fighting purposes.

There are several small subdivisions and trailer parks located in the near vicinity of St. Johns which have inadequate supply systems, especially with respect to providing storage for fire protection. Some of the trailer courts have been closed by the Department of Health Sercvices because of high TDS. Barium is a slight problem in the St. Johns municipal system, although it meets EPA Standards (Table 2-2).

Greer: Greer, situated within the Apache-Sitgreaves National Forest, is about 12 miles southwest of Springerville. It is located in the White Mountains Water Use Area.

> "Water supply in the Greer area is provided by private lodge, ranch well, spring fed systems, and the Greer Water Company.
>
> The water company has a spring source of supply which discharges to a 47,500 gallon storage tank and an older stone tank that has a capacity of about 61,000 gallons. The distribution network consists of three mains which serve approximately 50 customers." (10)

The rather high per-capita-use rate indicated in Table 2-3 is a result of transient population. The permanent population is small, but the total population increases by more than six times during the summer months. Most of this influx of people are families from the Phoenix and Tucson areas, who have summer homes located in the Greer area.

Water supply sources in Greer appear to be adequate to meet present and future needs. The number of systems, however, suggest the consideration of consolidation. This would allow for more economic operation and more effective delivery.

Storage facilities are generally adequate to meet domestic purposes, but provide no reserve for fire protection.

Water quality should be excellent, but minor problems have occurred in Greer due to the use of septic tanks. Recent sampling of Little Colorado River water by the Arizona Department of Health Services indicates that septic tank effluents are contaminating the surface waters passing through the area.

Bacteria counts of 1300, 2200 and 4500 col/100 ml have been recorded in the area for fecal coliform, intermediate coliform and fecal streptococci, respectively. These represent upper limits of the measurements but several counts exceeded the 200 col/100 ml (geometric mean) water quality criteria recommended by EPA for bathing or full body contact type of activity. Dissolved oxygen content, on the other hand, generally remained within the acceptable range. Measurements for this element ranged from 5.5 to 8.9 mg/1. These compare with a minimum concentration of 5.0 mg/1 recommended by EPA to maintain good fish populations in freshwater.

Other water quality data representive of the Greer area is given in Table 2-2. This data is for a well supplying the Big Bear Cabins Motel.

Nutroiso: Nutrioso is a small unincorporated community located about 15 miles southeast of Springerville. It is in the White Mountains Water Use Area.

Nutrioso is served by the Pinecrest Water Company from a single well (Table 2-1). Water quality is good (Table 2-2). There are no storage facilities, therefore, water for fire protection is not available.

The present population of 20 is projected to increase to only about 70 by 1990, and hold steady through 2020. The water system therefore, should be adequate to meet both present and future supply needs.

Springerville/Eagar: Springerville/Eagar are twin cities located in the south-central part of Apache County on the east bank of the Little Colorado River. They are in the White Mountains Water Use Area.

Domestic water for Eagar and Springerville is primarily obtained from wells. About 20 percent of the supply for Eagar comes from Coon's Springs located 8 miles southwest of town.

Eagar has three wells with a total capacity of 262 gpm, and has recently purchased one new well. The capacity of the new well is unknown, but the additional capacity should be adequate to supply existing needs.

The city of Springerville owns four wells with a combined capacity of 455 gpm. A fifth well has recently been completed through a government grant; its capacity

is unknown, but with the new well, water supplies for Springerville should also be adequate to meet present and near future needs.

Although the water supplies for the cities are adequate, their distribution systems are obsolete. "Most of the water mains within the two municipalities are three inches or less in diameter. Reportedly there are several thousand feet of water mains that are less than 1-inch in diameter." (10) While small diameter water mains are sometimes adequate in size to supply enough water to meet domestic purposes, they lack sufficient capacity to satisfy the demands for firefighting purposes.

The cities are in the process of improving their supply systems. The City of Springerville has recently completed the installation of 7700 feet of new pipelines, and has enlarged its pumping and storage facilities.

The total storage capacities for these two cities are respectively, 71,450 gallons for Eagar and 315,000 gallons for Srpingerville. Both communities need additional storage capacity to provide a reserve for fire protection.

Water quality in both communities is good with total-dissolved-solids being well below the recommended limit. Other pertinent water quality data for these two communities is shown in Table 2-2.

Vernon: Vernon is a small community located near the western edge of Apache County and the southern edge of the Little Colorado River Basin. It is in the White Mountains Water Use Area.

There are two water supply systems located in the near vicinity of Vernon which serve a population of 115. These are the Timber Knoll Water Company serving a subdivision located 3 miles west of Vernon, and the Vernon Water Users, Inc.

Water quality data is available for the Timber Knoll Water Company and is shown in Table 2-2. Existing data also indicates that the Vernon Water Users, Inc., has good quality water. These two systems have only minor storage facilities, 3000 and 5480 gallons, respectively. The storage facilities are not adequate to provide any reserve for fire protection.

Per capita water use is low, approximately 50 gpcd, which indicates that the water systems are inadequate to meet existing needs.

Concho: The Concho community is located along Highway 61 about 14 miles west of St. Johns. The community is generally rural in nature, and is located in The Concho Water Use Area.

There are two water systems located in the vicinity of Concho. These are the Concho Water Supply Company which serves the small community of Concho, and Liveco Water Company serving a small subdivision in the near vicinity of Concho.

The Concho Water Supply Company has only minimal storage (5000 gallons) and serves about 168 people. The Liveco Water Company has an estimated 250,000 gallons of storage serving approximately 340 people. The Liveco Company's storage capacity approaches that necessary to meet supply requirements for domestic purposes with a reserve for fire protection. Additional storage capacities are needed in the Concho Water Company's supply system. Other pertinent data relative to the number of wells and well capacities is given in Table 2-1.

The water quality of both of these systems appears to be good. Water quality data for the Liveco Water Company is given in Table 2-2.

Coconino County

Flagstaff: Flagstaff is located in Coconino County along the western edge of the Basin. It is in the San Francisco Peaks Water Use Area.

> "The water supply for Flagstaff is derived from four major sources: Lake Mary, a 737 surface acre lake located 15-miles southeast of the city; Lake Mary well fields; Woody Mountain well fields, located southwest of the City; and the Inner Basin of the San Francisco Peaks Mountain Range. The supply of water from two of these sources, Lake Mary and the Inner Basin, is directly proportional to annual rainfall and runoff, since both are infiltration and runoff collection systems." (3)

The Lake Mary system is capable of supplying three-million gallons per day (gpd) or 2080 gallons per minute (gpm), when water is available. The average yield is about 5,500 acre-feet per year, but is extremely variable. Evaporation and seepage losses also are significant.

There are presently five wells in the Lake Mary well field. Two of these wells have been abandoned. One new well is presently being drilled and a seventh well is planned. The present yield of the three producing wells is 2250 gpm.

In the Woody Mountain well field, there are six wells presently furnishing water. These wells have a combined capacity of 2370 gpm. A seventh well has been drilled in this area and tested at a rate of 900 gpm.

The Inner Basin supplies water from both groundwater pumping and spring development. Three wells in the area have a combined capacity of 1250 gpm and the spring developments have a capacity of 3-million gallons per day or 2080 gpm, when producing at maximum capacity. The recharge to the area is about 5,000 acre-feet per year, but the wells and springs fail to tap most of this water. The water not used leaks out and is probably discharged by Blue Springs located in the Little Colorado River Canyon. Thus, the wells and springs produce at peak capacity for only a relatively short time. New wells are planned in this area under future developments.

The combined maximum capacity of the present water supply system for Flagstaff is approximately 10,930 gpm. Although this appears to be adequate to meet present needs, with the steady population growth anticipated, future needs will be very difficult to satisfy. In fact, future growth may be limited by the water supply.

Water storage facilities in Flagstaff consist of two, 50-million gallon reservoirs and one, two-million gallon tank for a total capacity of 102-million gallons. This capacity exceeds present requirements for fire protection and general use purposes.

The water supply distribution system is also adequate for fire protection. Water quality is good with total-dissolved-solids (TDS) being considerable less than the 500 parts per million (ppm) recommended by EPA. Other pertinent data related to water quality for the City of Flagstaff is given in Table 2-2.

Tuba City: Tuba City is located in Tuba City Water Use Area in the northwest portion of the Basin.

Only limited data is available for this community with reference to its water supply. According to Bureau of Indian Affairs personnel, adequate waters are available in the aquifers located beneath or in the near vicinity of the city to supply the cities needs. New wells and distribution lines are being added using public health funds as they become available.

The city has four 50,000 gallon storage tanks and one 100,000 gallon tank. This is far from being adequate to supply the present population and provide a reserve for fire protection. The recommended storage for present conditions is approximately 1.9-million gallons.

Pertinent data with respect to the quality of the cities water supply is given in Table 2-2.

Navajo County

Keams Canyon: Keams Canyon is located near the west edge of Navajo County about 60 miles north of Holbrook. It is in the Hopi Water Use Area. The present population consists of 50 to 60 families or about 285 people. The water supply is very short, especially when the laundromat is in operation. The present water supply consists of two wells yielding approximately 75 gpm each, and spring development(s) capacity can be increased to 25 gpm through additional developement.

The community has two 300,000 gallon tanks. However, only about 500,000 gallons of the 600,000 gallon potential can be used. This is due to the location of the tanks with respect to elevation of the community.

Poor water quality is a major problem in the community. Two separate wells have had to be taken off-line due to high sodium concentrations. Barium concentrations from the springs and in some wells also exceed the recommended limits of the EPA. Data shown in Table 2-2, however, show that the tap water generally meets the EPA Standards.

Winslow: Winslow lies on the western edge of Navajo County along Interstate 40. It is in the Canyon Diablo Water Use Area.

The City of Winslow owns four wells. The maximum production capacity of these wells, as reported by the Arizona Department of Health Services, is approximately 2.8-million gpd or about 1950 gpm (Table 2-1). This exceeds the recommended capacity of 1060 gpm required to serve the present population. Present storage facilities amount to 3.52 million gallons, compared to a recommended storage of 3.33-million gallons to provide a reserve for fire protection. The distribution system has recently been improved and is considered adequate to meet present needs. Water quality meets health standards (Table 2-2).

Heber: Heber is located on the west side of Navajo County near the southern edge of the Basin. It is in the Chevelon Water Use Area. The water supply system at Heber consists of 6-inch lines, two wells of 500-foot depth, and storage facilities of 330,000 gallons. The combined capacity of the wells is unknown, but it is reported that one well produces at a rate of 67 gpm. This will supply a population of 482 at a rate of 200 gpcd. The present population of Heber is about 500. Storage facilities are generally adequate for fire protection and other uses. Water quality is good (Table 2-2).

Overgaard: Overgaard is located in Navajo County about 3 miles southeast of Heber. It is in the Chevelon Water Use Area.

> "Overgaard has three wells of approximately 500-foot depth. Two of the three wells are actually a part of the overall system and produce, individually, 75 gallons per minute. The third well is on standby basis and has a capacity of 500 gpm. Present storage is divide into two areas. One storage facility of 40,000 gallons is in the downtown area. The other, at the opposite end of town, consists of one tank of 125,000 gallons and a second pressure tank of 5,000 gallons." (8)

The water supply is adequate to meet present needs, but additional storage facilities are needed as a reserve for fire protection. Water distribution lines are also inadequate in several locations where diameters are less than 3 inches. Water quality is good as related to TDS (Table 2-2). Other water quality data was not available for this community.

Several subdivisions in the Overgaard area are linked to the Overgaard water system, but do not now function as a single entity.

> "Future plans call for joining of present systems, including that of Heber, and extension of facilities over a 20-square mile area. This will necessitate the joining of present systems and replacement of some lines to meet future requirements." (8)

Holbrook: Holbrook is located in the central part of Navajo County along Interstate 40. It is in the Holbrook Water Use Area.

In 1971, the water supply system in Holbrook consisted of three wells, storage facilities of 1.8-million gallons capacity, and piping of 2-, 4-, 6-, 8-, and 12-inch size. The three wells were capable of producing a maximum of 2,000 gpm. According to W.S. Gookin (8), this system was capable of supplying 1-million gpd in excess of the 1971 demands without adverse effects. The stated storage capacity, however, was slightly less than that recommended by American Insurance Association to meet the then existing needs for fire protection. (9)

The City has since made significant improvements in its water supply system by adding a new well, storage tank, and replacing a short section of one of its water mains. The system is now considered adequate to meet present and near future needs, except for some additional improvements needed in its distribution system.

The water quality is generally good, but there is a problem with high iron, and the TDS are slightly higher than that recommended by EPA (Table 2-2).

Joseph City: Joseph City is located ten miles west of Holbrook, along Interstate 40. It is in the Holbrook Water Use Area.

The water system consists of two wells of 300 gpm each, and storage facilities having a total capacity of 500,000 gallons. The system was improved in 1973 and is considered adequate to meet present needs. There is a need, however, for an additional well to serve as a reserve supply. The water quality slightly exceeds the recommended limits for TDS. Inorganic contaminants are within acceptable limits (Table 2-2).

Woodruff: Woodruff is a small unincorporated community located 15 miles southeast of Holbrook near the confluence of the Little Colorado River and Silver Creek. It is in the Holbrook Water Use Area.

The present water system consists of a single 4-inch well for domestic use and 1-inch and 2-inch distribution lines. The storage facility has approximately 12,000 gallon capacity. The water system is considered inadequate to meet present needs. Water quality is poor and declining and is occasionally murky with clay sediment. (8)

Shumway: Shumway is located about 6 miles south of Taylor or 9 miles south of Snowflake. It is located in the Snowflake Water Use Area.

The community of Shumway is scattered, and the present water supply consists of several individual wells. There are presently no storage facilities, except those necessary for home use. Thus, water for fire protection is not available. Water quality is good. (Water quality data presented in Table 2-2 for Taylor is representative of that found in the Shumway area.)

Although the present system is adequate to meet existing needs, as the population increases, there will be a need to develop a centralized water system for better efficiency and more economical operation.

Snowflake: Snowflake is located between Taylor to the south and Holbrook 28 miles to the north. It is in the Snowflake Water Use Area.

Present water service facilities consist of two wells with rated capacities of 350 and 1000 gpm, respectively. The 350 gpm well is used on a standby basis only. The water supply system has recently been updated and is adequate to meet present and near future needs. Storage facilities have a combined capacity of 1.1-million gallons and are adequate to meet reserve storage for fire protection. Water quality is good (see Table 2-2).

Taylor: Taylor is an incorporated community approximately 3 miles south of Snowflake. It is in the Snowflake Water Use Area.

The water system is municipally owned and consists of two wells of 600 and 450 gpm, respectively. The combined storage capacity is 426,000 gallons. This does not meet the required storage as recommended by the American Insurance Association for fire protection. (9) Distribution lines consist of 6-, 4-, 3-, 2½-, and 2-inch mains. Some recent changes have been made but additional improvements are needed in the storage and distribution systems. Water quality is good (Table 2-2).

Pinetop/Lakeside: Pinetop and Lakeside are unincorporated communities in Navajo County located along the extreme southern edge of the Little Colorado River Basin. These communities are in the White Mountains Water Use Area.

The Pinetop/Lakeside area is served by the Arizona Water Company and by several smaller water utility companies. The Arizona Water Company serves a portion of the Pinetop area, Woodland Park, White Mountain Country Club, and Lakeside. Other systems serving Pinetop include a citizens' owned water company and the Ponderosa Water Company serving the Pinetop Country Club. There are a total of 15 wells in these systems. The total capacity is unknown but the supply would be more than adequate to meet present needs if the systems were interconnected.

The smaller water companies serve small subdivisions located in the general area. The Arizona Water Company is in the process of enlarging its range to include these

systems. This will result in a more efficient system as available supply can be used over a wider area. Line sizes can be standardized and overall service should improve.

Maximum storage requirements for the Pinetop/Lakeside area are estimated to be almost 2-million gallons. The present systems provide approximately 2.08-million gallons. Although this appears to be adequate, it must be remembered that all systems are not interconnected.

The water quality is generally good, except there has been a bacteriological overgrowth problem in the citizens' owned water system in Pinetop. (8) Bacteria in the water is a result of the use of septic tanks and drainage fields in the region for sewage waste disposal. The geology of the region is not conductive to this type of sewage disposal. The region's geologic formation consists of metamorphic rocks, the voids of which have been sealed by a clay-soil composition. This material is impervious, making underground infiltration almost impossible below a depth of six feet. As a result, both surface water and groundwater supplies have been contaminated in the area. Improvements have been made in recent years to correct the problem.

Other water quality indicaters and their comparison to EPA Standards can be noted on Table 2-2 for both the Pinetop and Lakeside communities.

The Pinetop distribution lines are inadequate to meet fire fighting needs. These problems have been rectified to some extent through the installation of $700,000 worth of new improvements. There is still a need, however, for a new well and pumping plant for this system.

Many of the smaller distribution systems in the Pinetop/Lakeside area are in need of additional storage for fire fighting purposes.

Show Low: Show Low lies near the southern edge of the Basin. It is in the White Mountains Water Use Area.

The city owns four water wells for domestic and industrial purposes. Two of the wells are capable of pumping 600 gpm each. The third well which serves the Show Low Country Club, pumps 70 gpm and the fourth well serving Fairway Park is capable of pumping 140 gpm. This gives a total capacity for the city of 1410 gpm. This is adequate to supply existing needs.

Water storage consists of two metal reservoirs, one of which holds 1-million gallons and the other 500,000 gallons. This is adequate to provide a reserve for fire protection.

The distribution system, however, is not adequate. The existing system consists of a limited number of 6-inch and 8-inch mains with the remainder being of 2-inch size. This is not adequate for future service needs and is unsatisfactory for fire fighting purposes. For fire insurance rating, approved fire hydrants must be installed on 6-inch mains or larger.

Water quality data representative of the Show Low area is given in Table 2-2.

NEW MEXICO

Data was developed on four New Mexico communities: Gallup, Zuni, Gamerco, and Quemado (Tables 2-1 and 2-2).

Catron County

Quemado: Quemado is located in north-central Catron County. It is in the Carrizo Wash Water Use Area.

Quemado is unincorporated; the water system is privately owned. Water supply appears adequate for the present and the future. Storage should be added for additional fire protection. Expansion or replacement of the distribution system may be necessary by 1990. (5)

Water quality data indicate high fluoride concentrations (Table 2-2). (5)

McKinley County

Gallup: Gallup, the largest city in the New Mexico portion, is located in west-central McKinley County, along Interstate Highway 40. It is in the Upper Puerco Water Use Area.

According to city officials, Gallup added to its water storage in 1978, and two additional wells should be in operation by early 1979. Water system main lines need some expansion at the present time.

Numerous reports (13, 14, and others) have indicated that municipal water will be the main constraint to Gallup's future growth. Gallup may need additional water as early as 1985 depending on population growth and area development.

Studies, proposing to increase Gallup's municipal water supply, have centered on three alternatives:

1. Importation of 7500 acre-feet, temporarily reserved, from San Juan River Basin water: Presently this appears the best alternative. The Gallup-Navajo Indian Water Supply Project currently being planned by the Bureau of Reclamation (BR), would implement this alternative. BR estimates delivery of water to Gallup no sooner than 1990; the plan will require extensive review, Congressional approval, and a period for construction.

2. Development of various groundwater sources: The U. S. Geological Survey, under contract to BR, concluded there was no reliable groundwater source for long range municipal water supply (13). However, groundwater might be used as a short term supply or to supplement other sources.

3. Development of a surface water supply from the Puerco River, a tributary of the Little Colorado River: The estimated annual yield of 3,000 acre-feet, after reservoir losses, (14) is not enough to meet the total long term needs of Gallup. Construction of facilities for diversion, impoundment, and treatment would be necessary to develop this source.

For the long term, all these sources may be developed to the maximum economic and physical extent.

Compared to EPA Standards, Gallup water is hard and shows high sulfates and dissolved solids (Table 2-2).

Gamerco: Gamerco is located in west-central McKinley County, about five miles north of Gallup. It is in the Upper Puerco Water Use Area.

Gamerco is unincorporated; the water system is privately owned. Water supply and storage facilities appear to be adequate for the present and future. Expansion and some replacement of the distribution system may be necessary by 1990 (4).

Water quality data indicate high sulfates and dissolved solids (Table 2-2) (4).

Zuni: Zuni Pueblo is located in southwestern McKinley County on the Zuni Indian Reservation. It is in the Zuni Water Use Area.

In recent years, the Zuni water supply has improved rapidly under the Zuni Utility Authority. In 1978 nine wells served the needs of Zuni and the surrounding area. An additional well is planned. On-going projects will meet some of the existing needs for expansion or replacement of the distribution system. Combining of systems near Black Rock with Zuni would increase efficiency.

Groundwater can be developed to meet future needs. In the long term, surface water supplies from the Zuni River or its tributaries may also need to be developed. Water from existing or planned reservoirs may be needed for municipal use in the future.

Water quality data indicate high fluorides, dissolved solids, and alkaline pH values (4).

WATER DEMANDS-PRESENT AND PROJECTED

The total water withdrawal for mumicipal and industrial (M&I) purposes in the Little Colorado River Basin in 1975 amounted to 15,617 acre-feet. The depletion requirement for these purposes was estimated to be 7,800 acre-feet or 50 percent of the total withdrawal (1). The remainder was lost to deep percolation, evaporation, or to other beneficial or non-beneficial consumptive uses. Table 2-3 summarizes present and future withdrawals by community, county and water use area.

Present demands for M&I purposes in Arizona were developed from data obtained from several sources including: the U.S. Geological Survey, Arizona Department of Health Services, Bureau of Indian Affairs, published data, and interviews with community officials. In New Mexico, the 1975 uses and rates were obtained from available references and interviews with community officials.

Future M&I water needs for both the Arizona and New Mexico portions of the Basin are based on per-capita-use rates and projected populations. Projected population estimates were furnished by the Economic and Statistics Service (ESS). In Arizona the projected populations were derived from data originally developed by the Office of Economic Planning and Development. They are based on expected future economic activities and include a growth rate for industry. Thus, in developing future water requirements for Arizona, per-capita-use rates were varied by community, but were not increased based on projected population growth. That is, expected increases in per-capita-use rates were assumed to be accounted for in the projected population figures. In New Mexico, however, future water requirements are based on projected increases in both populations and per-capita-use rates (15).

PROBLEMS

Some problems in the Little Colorado River Basin have been experienced by several communities in the development of their water supplies. Some of the major problems

TABLE 2-3: PRESENT & PROJECTED POPULATION & M&I WATER WITHDRAWALS
LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO

LOCATION	Water Use Area	POPULATION 1/ 1975	1990	2000	2020	WATER DEMANDS (acre-feet per year) 1975 2/	1990 3/	2000 3/	2020 3/
Apache Co., Arizona									
Ft. Defiance, Window Rock & St.Michaels	CHN	5,400	7,780	9,990	17,400	621	894	1,149	2,000
Greasewood	CHN	1,200	1,340	1,440	1,690	214	240	257	300
Kin-Li-Chee	CHN	400	450	480	560	47	53	56	66
Subtotal	CHN	7,000	9,570	11,910	19,650	882	1,187	1,462	2,366
Chambers/Sanders	PRZ	385	700	850	975	112	204	247	284
Navajo	PRZ	100	210	270	335	20	42	53	67
Witch Well	PRZ	200	460	590	700	11	26	33	39
Subtotal	PRZ	685	1,370	1,710	2,010	143	272	333	390
St. Johns	STJ	1,840	4,500	5,110	6,340	235	575	653	811
Subtotal	STJ	1,840	4,500	5,110	6,340	235	575	653	811
Eagar	WHM	1,960	3,350	4,700	5,800	175	299	420	518
Greer	WHM	50	75	100	120	36	54	72	87
Nutrioso	WHM	20	70	70	70	2	3	3	3
Springerville	WHM	1,420	2,350	3,280	4,050	180	297	416	513
Vernon	WHM	115	115	115	115	7	7	7	7
Subtotal	WHM	3,565	5,960	8,265	10,155	400	660	918	1,128
Concho	CON	510	950	1,120	1,400	72	130	154	192
Subtotal	CON	510	950	1,120	1,400	71	130	154	192
TOTAL COUNTY		13,600	22,350	28,115	39,555	1,732	2,824	3,520	4,887

--See Footnotes at end of table--

TABLE 2-3: PRESENT & PROJECTED POPULATION & M&I WATER WITHDRAWALS
LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO
(CONTINUED)

LOCATION	Water Use Area	POPULATION 1/ 1975	1990	2000	2020	WATER DEMANDS 1975 2/ (acre-feet per year)	1990 3/	2000 3/	2020 3/
Coconino Co., Arizona									
Leupp	HOP	900	1,230	1,550	2,300	102	140	175	263
Subtotal	HOP	900	1,230	1,550	2,300	102	140	175	263
Flagstaff	SFP	31,370	47,920	57,970	78,000	3,977	6,055	7,338	9,874
Subtotal	SFP	31,370	47,920	57,970	78,000	3,977	6,055	7,338	9,874
Moenkopi	TUB	1,050	1,440	1,800	2,700	117	160	201	302
Tuba City	TUB	4,600	7,450	9,350	12,300	731	1,185	1,487	1,957
Subtotal	TUB	5,650	8,890	11,150	15,000	848	1,345	1,688	2,259
TOTAL COUNTY		37,920	58,040	70,670	95,300	4,927	7,540	9,201	12,396
Navajo Co., Arizona									
Hotevilla	BLM	900	1,050	1,200	1,500	101	118	135	168
Keams Canyon	BLM	290	290	290	290	24	24	24	24
Low Mountain	BLM	250	280	300	350	28	31	34	39
New Oraibi	BLM	600	840	1,100	1,800	67	94	123	201
Pinon	BLM	500	560	600	700	58	65	70	81
Polacca	BLM	500	560	600	700	56	63	67	78
Subtotal	BLM	3,040	3,580	4,090	5,340	334	395	453	591
Winslow	CDI	7,660	10,500	12,830	15,580	1,702	2,328	2,846	3,456
Subtotal	CDI	7,660	10,500	12,830	15,580	1,702	2,328	2,846	3,456
Heber	CHV	500	830	1,050	1,350	75	124	158	203
Overgaard	CHV	800	1,300	1,660	2,150	88	142	183	237
Subtotal	CHV	1,300	2,130	2,710	3,500	163	266	341	440

TABLE 2-3: PRESENT & PROJECTED POPULATION & M&I WATER WITHDRAWALS
LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO
(CONTINUED)

LOCATION	Water Use Area	POPULATION 1/ 1975	1990	2000	2020	WATER DEMANDS 1975 2/ (acre-feet per year)	1990 3/	2000 3/	2020 3/
Navajo Co., Arizona (Cont.)									
Holbrook	HOL	5,090	7,000	8,570	10,380	1,330	1,822	2,234	2,713
Joseph City	HOL	1,000	1,100	1,150	1,300	139	153	160	181
Woodruff	HOL	200	300	350	420	45	69	79	95
Subtotal	HOL	6,290	8,400	10,070	12,100	1,514	2,044	2,473	2,989
Shumway	SNO	200	650	750	900	22	71	82	99
Snowflake	SNO	2,570	4,260	5,310	6,490	474	782	976	1,194
Taylor	SNO	1,500	2,480	3,160	3,900	165	272	348	429
Subtotal	SNO	4,270	7,390	9,220	11,290	661	1,125	1,406	1,722
Pinetop/Lakeside	WHM	5,000	8,340	10,180	12,320	974	1,627	1,987	2,396
Show Low	WHM	3,380	5,580	6,930	8,440	503	831	1,032	1,257
Subtotal	WHM	8,380	13,920	17,110	20,760	1,477	2,458	3,019	3,653
TOTAL COUNTY		30,940	45,920	56,030	68,570	5,851	8,616	10,538	12,851
TOTAL ARIZONA		82,460	126,310	154,815	203,425	12,510	18,980	23,259	30,134
Catron Co., New Mexico									
Quemado	CAR	350	375	450	500	11	27	35	45
TOTAL COUNTY		350	375	450	500	11	27	35	45
McKinley Co., New Mexico									
Gallup	UPR	16,950	41,400	54,800	100,000	2,900	7,200	9,800	21,300
Gamerco	UPR	400	400	400	400	56	56	56	56
Zuni	ZUN	5,380	10,350	13,900	25,500	140	1,800	2,500	5,400
TOTAL COUNTY		22,730	52,150	69,100	125,900	3,096	9,056	12,356	26,756

TABLE 2-3: PRESENT & PROJECTED POPULATION & M&I WATER WITHDRAWALS
LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO
(CONTINUED)

LOCATION	Water Use Area	POPULATION 1/				WATER DEMANDS (acre-feet per year)			
		1975	1990	2000	2020	1975 2/	1990 3/	2000 3/	2020 3/
Valencia Co., New Mexico 4/		---	---	---	---	---	---	---	---
TOTAL NEW MEXICO		23,080	52,525	69.550	126,400	3,107	9,083	12,391	26,801
TOTAL BASIN		105,540	178,835	224,365	329,825	15,617	28,063	35,650	56,935

1/ ESS population estimates and projections for cities and towns developed in connection with river basin study.

2/ Data obtained from U.S. Geological Survey, Arizona Department of Health Services, Published Data (4,5, & 15), and interviews with community officials.

3/ Calculated from per capita use rates (15 & others) and ESS population projections.

4/ Because of its rural nature, no population figures, thus, no water demands were developed for the communities located in Valencia County, New Mexico.

include poor water quality, inadequate well yields, and lack of funds for development.

The major source of water for municipal and industrial purposes is groundwater. The quality of groundwater in the Little Colorado River Basin varies significantly. Some of the reasons are: quantity and quality of recharge; solubility of rock material in the water-bearing formations; capacity of the water-bearing formations to filter, absorb, precipitate or otherwise remove material from solution or suspension; and the amount of water removed from the water-salt solution through evaporation, transpiration, or through other forms of water losses.

There are three major multiple-aquifer systems that contain most of the available groundwater in the Basin. These systems are referred to as the C, D, & N Multiple-Aquifer sytems. The C-Multiple-Aquifer consists principally of the Shinarump member of the Chinle formation of Triassic age and the Coconino, De Chelly, and Glorieta Sandstones of Permian age. The D-Multiple-Aquifer system consists principally of the Navajo Sandstone of Jurassic and Triassic age.

Of the three major systems, the C System is the most important from the standpoint of a municipal and industrial water supply, and within the C System the Coconino Sandstone is the major aquifer. In general, the TDS in groundwater in the Coconino Aquifer increases northward from the Mogollon Rim, as the groundwater flows downdip toward the center of the Black Mesa structural basin. The aquifers located to the south and west of the Little Colorado River channel, however, generally yield waters of good quality.

The groundwater is highly mineralized in the St. Johns area and in the area north and northeast of Holbrook and Winslow. Poor groundwater quality has been experienced in the Keams Canyon and Witch Well study areas.

The water quality of each community investigated was compared to standards given in the Safe Drinking Water Act of 1974 (Table 2-2). Hardness ranges from soft to very hard; predominantly the water is hard but acceptable for M&I use. Locally, the concentrations of sulfates, fluorides, and dissolved solids may exceed the recommended limits.

A generalization of the groundwater quality for the Basin is shown on the Groundwater Availability Map(s), following page 5-22 (Section 5).

The depth to water is a factor which has a significant effect upon the development of groundwater as a water supply. Generally, as the depth to water increases, the cost of development increases. Depths are generally greatest along the southern part of the Basin from Clay Springs west to Flagstaff, and along that portion of the southern boundary of the Navajo and Hopi Indian Reservations which lie within Arizona. In these areas, the depth to water generally exceeds 500 feet with wells in New Oraibi, Hotevilla and Keams Canyon being drilled to depths of 900 to 1800 feet.

The capacities of the deep wells on the reservations are generally small, ranging from 4 to 75 gpm. Most of the communities on the reservations listed in Table 2-3 are in need of additional water supplies. Off-reservation communities that are in need of additional well capacities include Joseph City, Woodruff, Pinetop, Navajo, Chambers/Sanders area, Witch Well, and the Vernon and Concho areas. These are small, rural communities with limited populations. They are unincorporated and most lack organizational structure for undertaking system improvements. This is especially true in areas such as Concho, Vernon, Navajo, Chambers/Sanders, etc. Lack of organizational structure is also a problem on the Indian reservations.

Surface waters are being used only to a limited extent for M&I purposes within the Basin. The City of Flagstaff is the major user of surface waters for this purpose. Winslow has M&I storage rights from the Clear Creek Reservoir, however, this water is presently being used for recreation and irrigation.

Because of the intermittent nature of the streams in the Basin, surface waters must be impounded. Problems related to impounding and using these waters include water rights, high evaporation and seepage losses, poor water quality, and high cost.

Because of prior appropriations, surface waters available for M&I use are limited. Evaporation losses range from 4 to 5 feet per year.

Except for high sediment concentrations, the only problems with surface water quality, as inventoried, were in the Greer and Pinetop areas. In Greer, septic tanks are being used as the primary method of sanitary waste disposal. In this area, the Arizona Department of Health Services has verified that the surface waters are being contaminated by the effluent from septic tanks leach fields. In Pinetop, bacteriological overgrowth has been a problem. Sediment deposition, however, is a problem in most reservoirs located within the Basin.

Surface water quality tends to degrade in a downstream direction. This results from inflow of highly-concentrated salt water from springs, and an increase in sediment concentrations.

One of the most significant obstacles to improving the water supply for the various communities in the Basin, from either surface water or groundwater, is cost; including land rights costs. Although adequate water supplies may be available near the community, funds usually are not available for their development. There are grants and loans available to the communities from various sources, but generally, they are not adequate to meet the total need. Most of the grants or loans require matching or repayment funds, and since the communities are small, they have difficulty raising the matching funds or the revenue necessary to repay a government loan. Another obstacle is the lack of organizational structure in many areas of residential development.

Problems related to storage and distribution systems were discussed in the community descriptions, and will not be discussed further in this section of this report.

NEEDS BY TIME FRAME

Existing and projected needs for M&I water supply, storage, and distribution are given in Tables 2-3 and 2-4. Table 2-3 shows the present and projected water demands by time frame. Table 2-4 breaks the existing and projected needs into four separate categories. These are:

1) Replacement and/or modification (expansion) within distribution systems.

2) Water storage or additional storage facilities.

3) Combining of water systems for more economical delivery of services or consideration of municipal ownership and operation of water supply system.

4) Water supply augmentation.

The adequacy of existing water supplies was determined by comparing present capacities with existing demands. Recommended storage needs are based on the sum of three components (7):

TABLE 2-4
EXISTING AND FUTURE WATER SUPPLY AND DISTRIBUTION NEEDS
LITTLE COLORADO RIVER BASIN
ARIZONA AND NEW MEXICO

Community or Developed Area	Existing Needs 2/				Future Needs 1/ 2/											
					1990				2000				2020			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
ARIZONA																
Apache County																
Ft. Defiance	X	X		X												
Window Rock	X	X		X												
St. Michaels	X	X		X												
Greasewood	X	X		X												
Kin-Li-Chee	X	X		X												
Chambers/Sanders	X	X	X	X		X		X					X			
Navajo	X	X		X	X	X							X			
Witch Well	X	X		X					X	X						
St. Johns	X					X										X
Springerville/Eager	X	X	X		X	X				X		X				
Greer	X	X	X					X								
Nutrioso		X									X					
Vernon	X	X		X							X	X				
Concho (Area)		X		X	X						X	X				
Coconino County																
Leupp	X	X		X												
Flagstaff					X											X
Moenkopi	X	X		X												
Tuba City	X	X		X												
Navajo County																
Hotevilla	X	X		X												
Keams Canyon	X	X		X												
Low Mountain	X	X		X												
Oraibi (New)	X	X		X												
Polacca	X	X		X												
Pinon	X	X		X												
Winslow						X						X				
Heber						X		X								
Overgaard	X		X							X						
Holbrook	X					X							X			X
Joseph City	X			X												
Woodruff	X	X		X				X								
Shumway						X	X	X								
Snowflake						X										X
Taylor	X	X							X	X						X
Pinetop/Lakeside	X		X	X	X	X						X	X			
Show Low & Vicinity	X		X			X	X			X		X				

TABLE 2-4: (Continued)
EXISTING AND FUTURE WATER SUPPLY AND DISTRIBUTION NEEDS
LITTLE COLORADO RIVER BASIN
ARIZONA AND NEW MEXICO

Community or Developed Area	Existing Needs 2/				Future Needs 1/ 2/											
					1990				2000				2020			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
NEW MEXICO																
Catron County																
Quemado		X			X											
McKinley County																
Gallup	X							X								
Zuni	X	X	X					X								
Gamerco					X											
Valencia County 3/																

1/ Based on projected population levels.
2/ Needs Classifications
1. Replacement and/or modification (expansion) within distribution system.
2. Water storage or additional storage facilities.
3. Combining of water systems for more economical delivery of services or consideration of municipal ownership and operation of water supply systems.
4. Water supply augmentation.

3/ No data was developed for the small communities located in Valencia County, New Mexico.

1. Operating storage - necessary to supply peak water use periods, generally 20-40% of daily consumption.

2. Fire storage - increases with population; American Insurance Association has recommendations, which were used in the study (9).

3. Emergency reserve - usually about 25% of total storage, used to buffer unforeseen occurrences, such as pumping breakdown.

As was stated earlier, a simple "rule-of-thumb" states that recommended storage is equal to fire storage plus a one-day supply for domestic purposes. The one-day supply is based on a per-capita-use rate of 200 gpcd.

Judgment with respect to the adequacy of distribution systems was made on the stipulation that for fire fighting purposes, approved fire hydrants be installed on minimum 6-inch mains.

Water quality was also taken into account in determining the adequacy of present or projected water supply systems.

For most communities on Indian reservations, data was insufficient for making the necessary judgment in defining existing and projected water supply needs. Data also was not available on many of the smaller off-reservation communities. For most of the larger communities in the Basin, the data shown in Tables 2-3 and 2-4 give a reasonably good definition of the community's present and future water supply needs by time frame. Communities should make long-range plans to meet their water needs. They should consider location of future development and work out methods of financing.

MANAGEMENT AND CONSERVATION

The communities of the Basin have been and will be faced with the problems of peak use shortage or simply a water shortage. Water supply owners and managers have begun to adopt procedures aimed at conserving water. M&I water use can be reduced by controlling growth or the per-capita-use rate. Growth may be controlled by limiting permits, restricting utility expansion, or discouraging development in general. Per-capita-use rates may be controlled by attracting industries with low water use, promoting lawn reduction, or promoting multi-family developments. Other conservation techniques that may be used include: use of low water using fixtures and appliances, leak detection and repair, education, wastewater reuse, metering, pressure reduction and pricing.

It has been estimated that potential reductions ranging from 20 to 55 percent may be obtained through the use of low water using facilities (2). These facilities can be installed during new construction or by retrofitting older houses and other buildings with low water using types. The most common water use reduction devices include low flow shower heads, and devices installed in toilets to reduce the amount of water used in each flushing.

Nationwide, it has been estimated that about 12 percent of distributed water is lost by leakage and about 9 percent could be saved if proper maintenance and repairs were made (2). The amount of water lost in the Basin by this means is unknown.

An informed public is an absolute essential to any conservation program. This will necessitate a permanent, conscientious effort to inform the public. People must not only be aware of conservation techniques, but they must also be conscious of the need and benefits from saving water, and be willing to institute appropriate programs.

Wastewater reuse is not limited to large cities and towns. " A good example of reuse is backflushing of swimming pools onto landscaped and lawn area rather than to the sewer system or the street...However, the reuse of large amounts of water normally involves commercial, industrial, and/or agricultural users." (2)

Metering is an effective way of reducing water use. Through metering, the consumer becomes aware that cost is related to the amount of water used; i.e., the more water used, the higher the cost. Cost is an effective deterrent to waste, although it is often only a short term deterrent as people adjust to paying higher bills.

Excessive pressure often causes high and inefficient water use. With high pressures, shower heads emit more water than is necessary, and sprinkler systems emit fine sprays which tend to increase evaporation losses. Pressures within individual systems, however, may very greatly. Most large systems have pressure zones with the highest elevation receiving water at a minimum acceptable pressure level. To cause any pressure reduction without adversely affecting the higher elevation user, the number of zones would have to be increased. This is usually expensive, and generally is not justified based on the amount of water saved.

Price structuring is a viable alternative for conserving water and should be encouraged. Most water rates are structured to meet the level of revenues needed to maintain a municipal or private water system as an operating unit. Most municipal customers are not willing to accept a rate structure higher than that necessary to pay the systems' costs as a means to effect water conservation.

Some communities, however, have instituted limited programs to lessen the chance of peak use shortages. These include:

1) Abandonment of summer rates, also known as "irrigation rates."

2) Construction of additional storage to ease peaking problems.

3) Daily time schedules or prohibiting the use of water for lawn watering. car washing, etc.

Although these programs are effective in reducing "peak use rates", they do not necessarily reduce the total amount used. As water shortages become more acute, many of the water conservation techniques discussed earlier will need to be put into practice. This will prolong the availability of present supplies.

ALTERNATIVE SOURCES OF SUPPLY

SURFACE WATER

In Arizona, there are very few opportunites in the Little Colorado River Basin for increasing M&I water supplies from surface water. This results from prior appropriation of these waters, primarily for irrigation, and limited runoff conditions within the Basin. Communities in Arizona where additional storage reservoirs have been proposed for M&I purposes include the cities of Flagstaff, Winslow-Holbrook, Springerville-Eagar-St. Johns and the Ft. Defiance-Window Rock areas. Except for the Ft. Defiance-Window Rock area, reconnaissance type feasibility studies for each of the listed proposals have been made by the U.S. Department of Interior, Bureau of Reclamation, Region 3. (12,16) Also included in the Bureau's investigations was a proposal to supply water for the city of Gallup, New Mexico, utilizing the waters from Black Creek at the Houck Dam and Reservoir site. (12,14) None of the projects have been installed.

Other proposals for surface water supply for the city of Flagstaff includes water from the Tremaine-Soldier Annex Lakes; from an intermittent storage lake on Anderson Mesa; and from Mormon Lake. These proposals are described in Section 4 of this Appendix.

In the Ft. Defiance-Window Rock area, the Navajo Tribal Utility Authority has contracted with a private consulting firm to investigate the possibility of constructing a storage reservoir on Quartzite Canyon for the purpose of storing water for M&I purposes. This canyon is a tributary to Bonito Creek and is located north of Ft. Defiance. Other possible storage sites are located on Blue Canyon west of Ft. Defiance, Bowl Canyon northeast of Navajo, and on upper or lower Black Creek.

Surface water is available for use within the New Mexico portion of the Little Colorado River Basin (11). Several reservoirs exist along the Zuni River and its tributaries. The Yellowhouse Reservoir, near the present Black Rock Reservoir, is being planned by the Bureau of Reclamation. However, none of the existing or planned reservoirs have M&I water as a purpose. The previously described proposal to divert approximately 7,500 acre-feet of surface waters from the San Juan River Basin is another alternative source of water for the City of Gallup (Page 2-17).

Another alternative source of surface waters, in both Arizona and New Mexico, is that of conversion. As the demand for M&I water increases and other alternative sources become scarce or more expensive, there will be increasing pressure to convert present surface water supplies from such uses as irrigation to M&I purposes. This will require changes in existing water rights and detailed investigations to determine the most feasible alternative for supplying M&I needs.

GROUNDWATER

For most communities in the Basin, groundwater has proven to be the least costly alternative for water supply development. In New Mexico, present M&I well fields are located in alluvial aquifers that are stream connected. These aquifers are relatively thin and are of limited capacity. Groundwater is available within the area, but depending on the individual aquifer, low yields, poor quality, excessive depths to water, or excessive distances from source to use areas hamper development of the groundwater resource (16).

In Arizona, M&I well fields are located in the various multiple-aquifer systems described previously. A general indication of the availability and quality of groundwater in the Basin is shown on the map(s) entitled "Availability of Groundwater for Irrigation, Municipal, or Industrial Use in the Little Colorado River Basin" following page 5-22 (Section 5). This map(s) can be used as a guide by community planners to determine the general locations of groundwater for possible development, but it must be recognized that detailed investigations will be needed in order to make sound decisions concerning actual development.

USDA AND OTHER PROGRAMS

Within the U.S. Department of Agriculture, programs of the Soil Conservation Service (SCS) and the Farmers Home Administration (FmHA) can provide technical and financial assistance to state and local sponsors.

SOIL CONSERVATION SERVICE

The Watershed Protection and Flood Prevention Act (PL-566) authorizes the Secretary of Agriculture who, in turn, has authorized the SCS to cooperate with local

sponsors in planning and installation of structural measures for flood prevention and other purposes including municipal and industrial water supply. No potential projects, however, were identified during the study. SCS also provides resource data such as soils information and snow survey data. The SCS snow survey data is used to predict seasonal yield for M&I use in some localities.

FARMERS HOME ADMINISTRATION

FmHA can provide loans to cities of population less than 10,000 if no other reasonable credit is available. Loans may be used to finance any local cost-sharing items as required.

FmHA will administer a new program designed to assist areas highly impacted by activity in uranium and coal mining. Within selected states, the governor's office selects the impacted areas, which must meet a list of criteria for eligibility. Grants may soon become available for: (1) planning - 100% federal funds, (2) land acquisition - 75% federal funds, and (3) land or project development - 75% federal funds. Water supply projects would be eligible for grants depending on the priorities of each impacted area. The Gallup area will probably be identified as an impacted area.

OTHER PROGRAMS (6)

State planning offices and the councils of governments can help communities determine what types of financial assistance might be available for M&I water development. Financial assistance, available under certain rules and regulations, is offered by various federal or State agencies including:

1. Economic Development Administration, Department of Commerce - offers grants and loans for public facilities, including water systems, within a redevelopment area or designated economic development center - in this case the Four Corners Economic Development Region.

2. Indian Health Service, Department of Health, Education, and Welfare - offers project grants to alleviate lack of safe water supplies for federally recognized tribes and tribal organizations of Native American, such as the Zuni, Hopi, and Navajo Indians.

3. Environmental Improvement Division (EID) - a State of New Mexico agency, within the Department of Health and Social Services, that administers grants authorized by the Water Supply and Construction Act of New Mexico.

   For communities with populations greater than 5,500, EID can provide grants (maximum of $100,000) up to 25 percent of the cost for water supply projects. For communities less than 5,500 an EID grant may provide up to 40 percent of the cost of a project. Certain costs, e.g., land rights and project administration, must be borne by the local communities.

Technical assistance is also offered by various agencies including:

1. Bureau of Reclamation, Department of Interior - plans large projects such as the previously discussed Gallup-Navajo Indian Water Supply Project.

2. Geological Survey, Department of Interior - gathers basic data on ground and surface waters.

3. Office of Water and Hazardous Materials, Environmental Protection Agency - offers technical assistance to assure water supply systems meet minimum national standards for protection of public health. Administers Federal Safe Drinking Water Act of 1974 (Public Law 93-523).

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SECTION 3

RURAL DOMESTIC AND LIVESTOCK WATER SUPPLY

SECTION 3

Rural Domestic and Livestock Water Supply

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SECTION 3

RURAL DOMESTIC AND LIVESTOCK WATER SUPPLY

INTRODUCTION

The amount of water used for rural domestic and livestock purposes in the Little Colorado River Basin is small in comparison to other uses (Table 3-3). Of the estimated 162,200 population, over 65 percent reside in cities and towns (see Section 2 of this Appendix, "Municipal and Industrial Water Supply"). Many small communities such as Greer, Nutrioso, and Vernon have populations of 100 or less and could be classified as rural in nature; however, these were included in the M&I Section of this report. (4)* Therefore, for the purposes of this writeup, rural domestic water will be limited to that portion of the Basin's population that is not specifically accounted for in the list of communities given in the M&I Section.

Most of the water used for rural domestic purposes is obtained from pumped groundwater, although spring development is also used in some locations. In many rural areas, water is scarce, if not non-existent. In other areas, the depth to water or poor water quality may limit the availability of an adequate water supply. (See Groundwater Availability Map, following page 5-22, Section 5).

Water for livestock is also scarce in many areas of the Basin. Flows on many of the drainage courses on which stock ponds have been constructed are infrequent and erratic. In order to provide carryover between streamflows, the tendency has been for the stockmen to make their reservoirs large; thus, creating large surface areas which, in turn, increases the amount of water lost due to evaporation and seepage. The amount of water lost in the ordinary stock pond to these two causes is large in comparison to that consumed by livestock. (See Tables 3-2 and 3-4).

In addition to stock ponds, water for livestock in obtained from wells, springs and live streams. Water harvesting, through artificial catchments, also supplies water to a limited extent in certain locations. Associated facilities used to distribute the water include storage tanks, pipelines, and watering troughs (Table 3-1).

The arid or semi-arid range areas provide a unique opportunity for range management. Advantage is taken of the fact that water is a "key" resource on the range; providing or withholding water for livestock can be used to facilitate livestock management. For example, such use of water as a control in many instances limits the necessity for construction and maintenance of costly fencing projects. (3)

The purpose of this paper is to identify areas in need of rural domestic and livestock waters, and suggest methods of supplying these needs. Data is presented by water use area, county and total Basin. In Arizona, the water use areas (with minor modifications) are those defined by the Arizona Department of Water Resources and the U. S. Geological Survey in their studies of the groundwater resources for the State. In New Mexico, boundaries for the water use areas follow drainage divides based on the boundaries of the Hydrologic Unit Map - 1974. (12) (See Water Use Area Map on the following page.

* Numbers in parentheses refer to references listed in the back of this Section of the Appendix.

PRESENT WATER SUPPLY

Water supplies for rural domestic purposes are basically from pumped groundwater. Spring development, however, has played an important role in or near the National Forest. On Indian reservations, water for domestic purposes is scarce. Wells for individual families are few and far between. In many areas, centrally located wells may serve several square miles with people hauling water over long distances. In other areas, the depth to water and poor water quality limit the development of adequate water supplies for rural communities. For these reasons, per capita consumptive use rates are small, ranging from 50 to 60 gallons per-capita-day (gpcd) or less.

Water for livestock is supplied from three major sources. These are stock ponds, springs, and wells. Artificial catchments are also being used to a limited extent for supplying livestock water. Better distribution of available supplies is being made through the use of storage tanks, pipelines, and watering trough installations. This is especially true in relation to springs and well developments, and in connection with the artificial catchments. In most of the Basin, geologic formations yield enough water locally to supply domestic and livestock needs, but few can be considered good aquifers. Most existing wells used for livestock and domestic purposes are comparatively deep, yields are low, and quality ranges from good to poor.

Water quality requirements for domestic and livestock use are substantially different. The July 1976 edition of EPA's, "Quality Criteria for Water" establishes a criterion of 250 mg/l for chlorides and sulfates in domestic water supplies. While not setting a limit for total dissolved solids (TDS), this reference refers to a study in California which showed waters with TDS of approximately 1,300 mg/l were rated as "unacceptable."

Livestock, on the other hand, are much less susceptible to the physiological hazards of saline waters. The 1972 edition of "Water Quality Criteria" contains a guide (Table V-3) for evaluating the expected impact. Generally, water with TDS less than 3,000 mg/l should be very satisfactory for livestock use. Even with concentrations of 6,000-7,000 mg/l TDS, the water could be used with reasonable safety for dairy and beef cattle, sheep, and horses.

Stream-valley alluvium or bolson deposits generally yield good quality water with total dissolved solids of 250 to 1,000 mg/l. More mineralized, but still of adequate quality describes the water obtained from intrusive and volcanic rocks. Sedimentary rock commonly yields highly mineralized water with total dissolved solids greater than 1,000 mg/l. (9) (The reader is referred to the Groundwater Availability Map following page 5-22 (Section 5) and to Reference No. 4. These two references will give the reader a general understanding of the quality of groundwater available in various parts of the Basin.

In New Mexico, groundwater supplies rural domestic use almost totally, while the sources for livestock water are generally considered to be groundwater and surface water in equal proportion. (11)

Water supply for livestock, however, is variable over the Basin. Within the Basin, there are an estimated 8,340 livestock watering facilities. These facilities are distributed within the Basin by water use area and by number and type as shown in Table 3-1. The data for Arizona was developed from 1971 General Highway

LEGEND

ARIZONA

BLM	Black Mesa Area
BOD	Bodaway Mesa Area
CDI	Canyon Diablo Area
CHV	Chevelon Area
CHN	Chinle Valley Area
CON	Concho Area
HOL	Holbrook Area
HOP	Hopi Area
KAI	Kaibito Plateau Area
PRZ	Puerco - Zuni Area
STJ	St. Johns Area
SFP	San Francisco Peaks Area
SNO	Snowflake Area
TUB	Tuba City Area
WHM	White Mountain Area

NEW MEXICO

CAR	Carrizo Wash Area
UPR	Upper Puerco Area
ZUN	Zuni Area

NOTE:
In Arizona, Water Use Areas are Ground Water Study Areas; in Mew Mexico they represent Hydrologic Boundaries.

BY
ARIZONA WATER COMMISSION
NEW MEXICO STATE ENGINEER
AND
U.S. DEPARTMENT OF AGRICULTURE

WATER USE AREAS
LITTLE COLORADO RIVER BASIN
ARIZONA AND NEW MEXICO

MARCH 1981

10 0 10 20 30 40 MILES

SCALE 1:2,000,000

Source:
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series.
Thematic detail compiled by state staff.

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE USDA SCS PORTLAND OR 1981

M7-OL-24030-18

TABLE 3-1: LIVESTOCK WATER FACILITIES
LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO, 1975

WATER USE AREA	TYPE AND NUMBER OF FACILITIES				
	Catchments	Ponds	Wells & Tanks 1/	Springs	Total
		(No.)	(No.)	(No.)	(No.)
Apache Co., Arizona					
Chinle Valley (CHN)	0	181	87	27	295
Concho (CON)	0	70	40	6	116
Puerco-Zuni (PRZ)	0	360	175	2	537
St. Johns (STJ)	0	157	96	25	278
White Mountains (WHM)	0	331	67	142	540
Subtotal		1,099	465	202	1,766
Coconino Co., Arizona					
Black Mesa (BLM)	0	130	23	29	182
Bodaway Mesa (BOD)	0	38	3	0	41
Canyon Diablo (CDI)	0	556	52	39	647
Chevelon (CHV)	0	204	11	48	263
Hopi (HOP)	0	67	5	6	78
Kaibito Plateau (KAI)	0	67	26	0	93
San Francisco Peaks (SFP)	0	416	75	34	525
Tuba City (TUB)	0	69	34	81	184
Subtotal		1,547	229	237	2,013
Navajo Co., Arizona					
Black Mesa (BLM)	0	413	89	151	653
Canyon Diablo (CDI)	0	10	1	0	11
Chevelon (CHV)	0	276	31	16	323
Holbrook (HOL)	0	218	47	1	266
Hopi (HOP)	0	483	124	77	684
Puerco-Zuni (PRZ)	0	22	6	0	28
Snowflake (SNO)	12	209	36	8	265
White Mountains (WHM)	0	55	0	4	59
Subtotal	12	1,686	334	257	2,289
TOTAL ARIZONA	12	4,332	1,028	696	6,068

1/ Wells and storage tanks

TABLE 3-1: LIVESTOCK WATER FACILITIES
LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO, 1975
(CONTINUED)

WATER USE AREA	TYPE AND NUMBER OF FACILITIES				
	Catchments	Ponds	Wells & Tanks 1/	Springs	Total
		(No.)	(No.)	(No.)	(No.)
Catron Co., New Mexico					
Carrizo Wash (CAR)	0	436	423	82	941
Subtotal	0	436	423	82	941
McKinley Co., New Mexico					
Upper Puerco (UPR)	0	449	145	32	626
Zuni (ZUN)	0	257	70	20	347
Subtotal	0	706	215	52	973
San Juan Co., New Mexico					
Upper Puerco (UPR)	0	15	0	0	15
Subtotal	0	15	0	0	15
Valencia Co., New Mexico					
Carrizo Wash (CAR)	0	13	22	1	36
Zuni (ZUN)	0	106	171	30	307
Subtotal	0	119	193	31	343
TOTAL NEW MEXICO	0	1,276	831	165	2,272
TOTAL BASIN	12	5,608	1,859	861	8,340

1/ Wells and storage tanks

Maps for each county and from other sources. The highway maps were used to estimate the number and location of stock ponds, springs, windmills and storage tank installations. The data was then updated through contact with personnel in the local Soil Conservation Service (SCS) field offices. Data from the U.S. Geological Survey was used in estimating the total number of wells being used for livestock purposes. On Indian reservations, both the Bureau of Indian Affairs and the Indian tribes themselves, provided data. New Mexico's main sources for number and type of livestock water facilities include U. S. Geological Survey Quadrangle Maps, New Mexico Water Resources Assessment, and Zuni Soil and Range Inventory.

It was estimated that the average annual inflow to the more than 5,600 stock ponds is about 168,400 acre-feet. Most of this water, however, either passes through the structures or is lost to evaporation or seepage (see Table 3-2). Only about 8,400 acre-feet is estimated to be available on an average annual basis for livestock consumption.

Many of the ponds go dry during extensive periods of no rainfall. In areas of insufficient water, ranchers have had to haul water or move their livestock to fields where the water supply was adequate. SCS field personnel in Coconino County estimated that approximately 60 to 70 percent of the stock ponds, as identified from the General Highway maps, are unreliable -- if reliability is defined as having sufficient water 8 out of 10 years. It is estimated that there is a need for a 100% to 200% increase in the number of reliable watering facilities for livestock.

The following are general descriptions of the present water supplies for each of the water use areas listed in Tables 3-1 & 3-2. Other data pertinent to the descriptions are given in Tables 3-3, 3-4 and 3-5. Little data is available with reference to rural domestic water supplies, thus, most of the discussions will be limited to supplies used for livestock purposes. The reader, however, is referred to Section 2,"Municipal and Industrial Water Supply" for descriptions of several of the smaller rural communities located within each of the water use areas. Also, many of the general descriptions, although referenced to livestock water, would also apply to the rural domestic water situation.

APACHE COUNTY, ARIZONA

Chinle Valley (CHN)

Water supplies in this area are rated as fair, except in the southern and western sections where they are rated as poor. Wells, springs and live streams are the main sources, however, many of these decline or fail during mid-summer -- especially during dry years. A total of 80 wells have been developed for livestock. These have an average depth of 450 feet with an average yield of 27 gpm (gallons per minute). Several of the wells have gone dry or have been abandoned.

The present water supply is generally considered inadequate, and there is a need for more and better distribution of large storage tanks with associated pipelines and properly located drinkers. There are many critically eroding watersheds in this study area, and sedimentation is a major problem.

Concho (CON)

Most of this area has a good livestock water supply. It is furnished by wells and springs. Several of the ranchers also have installed pipelines. This allows for a better distribution of the drinking facilities.

TABLE 3-2: ESTIMATED STOCK POND AVERAGE ANNUAL INFLOW, STORAGE, AND EVAPORATION
LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO

WATER USE AREA	No. of Ponds	Average Annual 1/ Inflow		Average Annual 2/ Evaporation	Average Annual 3/ Storage
		(In.)	(Ac. Ft.)	(Ac. Ft.)	(Ac. Ft.)
Apache Co., Arizona					
Chinle Valley (CHN)	181	0.17	2,500	590	270
Concho (CON)	70	0.35	2,000	250	100
Puerco-Zuni (PRZ)	360	0.14	4,000	1,200	540
St. Johns (STJ)	157	0.20	2,500	560	240
White Mountains (WHM)	331	1.34	35,500	1,200	500
Subtotal	1,099		46,500	3,800	1,650
Coconino Co., Arizona					
Black Mesa (BLM)	130	0.11	1,100	440	200
Bodaway Mesa (BOD)	38	0.10	300	140	60
Canyon Diablo (CDI)	556	0.51	22,700	1,900	830
Chevelon (CHV)	204	1.27	20,700	700	300
Hopi (HOP)	67	0.10	500	220	100
Kaibito Plateau (KAI)	67	0.14	700	240	100
San Francisco Peaks (SFP)	416	0.21	7,000	1,500	620
Tuba City (TUB)	69	0.10	600	250	100
Subtotal	1,547		53,600	5,390	2,310
Navajo Co., Arizona					
Black Mesa (BLM)	413	0.11	3,600	1,400	620
Canyon Diablo (CDI)	10	0.51	400	40	20
Chevelon (CHV)	276	1.27	28,000	950	410
Holbrook (HOL)	218	0.15	2,600	740	330
Hopi (HOP)	483	0.10	3,900	1,600	720
Puerco-Zuni (PRZ)	22	0.14	200	70	30
Snowflake (SNO)	209	0.49	8,200	750	310
White Mountains (WHM)	55	1.34	5,900	200	80
Subtotal	1,686		52,800	5,750	2,520
TOTAL ARIZONA	4,332		152,900	14,940	6,480

TABLE 3-2: ESTIMATED STOCK POND AVERAGE ANNUAL INFLOW, STORAGE, AND EVAPORATION
LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO
(CONTINUED)

WATER USE AREA	No. of Ponds	Average Annual 1/ Inflow (In.)	Average Annual 1/ Inflow (Ac. Ft.)	Average Annual 2/ Evaporation (Ac. Ft.)	Average Annual 3/ Storage (Ac. Ft.)
Catron Co., New Mexico					
Carrizo Wash (CAR)	436	0.25	8,700	250	650
Subtotal	436		8,700	250	650
McKinley Co., New Mexico					
Upper Puerco (UPR)	449	0.25	9,000	450	670
Zuni (ZUN)	257	0.25	5,100	260	390
Subtotal	706		14,100	710	1,060
San Juan Co., New Mexico					
Upper Puerco (UPR)	15	0.75	900	20	20
Subtotal	15		900	20	20
Valencia Co., New Mexico					
Carrizo Wash (CAR)	13	0.20	200	10	20
Zuni (ZUN)	106	0.20	1,700	90	160
Subtotal	119		1,900	100	180
TOTAL NEW MEXICO	1,276		25,600	1,080	1,910
TOTAL BASIN	5,608		178,500	16,020	8,390

1/ Average annual inflow based on unit runoff (see Unit Runoff map following page 5-16, Section 5), and average drainage area size of 1.5 sq. miles per structure.

2/ In Arizona evaporation loss estimated assuming average surface area of 0.75 ac/pond (max. surface area = 1.5 ac) and using mean lake evaporation as shown on map following this page. In New Mexico, evaporation loss was derived from New Mexico Water Resources Assessment.

3/ Estimated carryover storage based on 1.5 ac-ft/pond.

Puerco-Zuni (PRZ)

A small portion of this water use area is located in Navajo County, but the following discussion is referenced to the total study area.

The lack of water is a critical problem in the northern and central portions of this study area. A large part of the area is sandy and seidmentaion and stock pond seepage are major problems. The soils in the southern part contain higher amounts of clay, and stock ponds tend to hold water. There is still a problem with erosion, however, and reservoirs soon fill with sediment.

There are several springs within the study area and several ranchers have developed wells. A total of 181 wells and storage tanks (Table 3-1) have been developed for livestock; 80 wells on Indian lands and 101 wells and tanks on non-Indian lands. The average depth of the wells is about 400 feet with an average yield of about 24 gpm.

Because of high initial cost and unfamiliarity, many ranchers in the area dislike pipelines. Watering facilities, therefore, may be several miles apart. In some instances, livestock must walk long distances to water. There is also a problem with "alkali" in some parts of the study area, and in the uranium mining area, there is a problem with water quality due to leaching from mine tailings.

Suggested alternative water sources for this area include horizontal wells, storage tanks and pipelines, and properly located drinkers.

St. Johns (STJ)

The soils in the northern part of this water use area are heavy clays and stock ponds are effective if built with adequated depths. Leakage is more of a problem in the southern half of the study area. Erosion and sedimentaion is a problem over the total study area. Very little groundater is used because of poor quality. Shallow well water is high in TDS - good water is deep and costly. (See Groundwater Availability Map, following page 5-22, (Section 5).

White Mountains (WHM)

Although it does not have an adequate water supply for livestock, the eastern portion of this study area is one of the best watered areas in the Basin. There are numerous springs, ponds, and live streams located in the region, and runoff is high. Runoff is also high for the western half of the study area (including the Navajo County portion), but the soils are very porous (cinders, basalts, etc.), and are not suited for stock pond development. Ranchers,therefore, must develop wells or depend heavily upon live streams or springs developments.

The community of Vernon, which is also located in the western half of the study area, is in need of a good communty water supply. Several of the residents within the community are interested in developing a central water supply system (see description of Vernon's water supply system as described in Section 2 of this Appendix). Water quality is generally good within the study area for both surface and groundwater supplies.

COCONINO COUNTY, ARIZONA

Bodaway Mesa (BOD)

There is very little water development in this area for any purpose. The only sources of water are a few shallow wells; catchment basins (not maintained or

LEGEND

—50— Evaporation (In Inches)

MEAN ANNUAL LAKE EVAPORATION

LITTLE COLORADO RIVER BASIN
ARIZONA AND NEW MEXICO

APRIL 1981

10 0 10 20 30 40 MILES
SCALE 1:2,000,000

Source:
After Farnsworth, Peck, and Thomson by private communication.
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series.
Thematic detail compiled by state staff.

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functioning); and some small intermittent streams in the canyon bottoms. There have been only 3 wells developed in the area for livestock. One of these is dry or has been abandoned. The average depth is about 30 feet with an average yield of 5 gpm. The development of deeper wells, pipeline with drinkers, and artificial catchments offer the best solutions for increasing the water supply for this area.

Black Mesa (BLM) (See write-up under Navajo County, page 3-10).

Chevelon (CHV)

Only about one-half of this water use area lies within Coconino County. The other half is located in Navajo County, but for ease of presentation, the total area will be discussed in this section of the report. Water supplies for livestock in the southern half of the study area generally are considered adequate. In this region, precipitation usually exceeds 16-inches and runoff is high. The only problem is a need for better distribution of watering facilities to better manage the ground cover.

The same, however, cannot be said for the northern half of this water use area. In the northern region, there are several sections that have been identified as being water deficient. This portion of the study area is probably one of the worst areas for livestock water in the Basin. The area is cut by deep canyons. At times, water is available in the canyons but the task of raising the water from the incised channels is impractical due to the heights involved. Pond sites and well sites are very limited. The best solution appears to be artificial water catchments. Many natural areas for this type of development exist, but they have not been developed because of cost and isolation of the sites. There is only a minor problem with sedimentation in the area.

Canyon Diablo (CDI)

Based on data developed from the General Highway Maps, this area is one of the best livestock watered areas in the Basin (Table 3-1). The number of stock ponds and other watering facilities are generally adequate for supplying the necessary water for livestock purposes. There are, however, scattered locations in the east-central portion of the study area that have been identified as having insufficient water. It must also be recognized that although the number of watering facilities appears to be adequate, there is a problem with proper distribution, and many of the stock ponds go dry during the summer. As stated earlier, personnel in the local SCS Field Office estimated that approximately 60 to 70% of the stock tanks identified from the General Highway Maps might prove to be unreliable if we define reliability as having sufficient water in 8 out of 10 years.

The area with the most dependable source of water is along the southern one-third of the study area, where the precipitation generally exeeeds 16-inches, and runoff is high. Spring runoff is the most dependable source of water for this region. Summer thunderstorms, though scattered, are more dependable in the south than those experienced in the northern two-thirds of the study area. Another problem experienced in the northern portion of the study area (including the small portion located in Navajo County) is that groundwater is deep and often difficult to locate. This has limited the development of present water supplies in the northern part basically to surface waters.

Hopi (HOP) (See write-up under Navajo County, page 3-11).

Kaibito Plateau (KAI)

Water supplies in this area are considered inadequate to meet the present needs. This is due mainly to inadequate distribution of watering facilities. There are a total of 26 wells which have been drilled in the area for livestock. Five of these are dry or have been abandoned. Additional wells, plus collection tanks, pipelines, and drinking facilities offer the best alternatives for increasing the present supplies. Artificial catchments and horizontal wells also hold promise as possible alternatives.

San Francisco Peaks (SFP)

The present water supply in this study area is similar to that described for the southern half of the Canyon Diablo Water Use Area. There are large blocks of rangeland located both north and south of the Wupatki National Monument, along the eastern edge of the study area, that have been identified as having insufficient water. There are also a few sections scattered along the western edge of the study area, between the Kaibab and Coconino National Forest, that also have been identified as being water deficient. The depth to groundwater is deep. Most of the area has been drained of the shallow groundwater resources through deep incisement of the Colorado and Little Colorado River channels. The best alternatives for improving the present water supplies appear to be extensive pipeline developments with drinking facilities, artificial catchments pond sealing, and construction of new ponds. Pipeline development with drinkers is already an accepted practice in the study area.

Tuba City (TUB)

Tuba City, like the Bodaway Mesa Area, has a rather severe water shortage. This is especially true during the summer months. Canyon streams dry up and flows from wells decrease. Summer evaporation from open stock ponds is high. Most of the earthern dams in the area are porous and will not hold water. Catchments have been used, but they are not protected or maintained. There are a total of 32 wells in the area for livestock, but 4 of these are dry or have been abandoned. The average depth is 358 feet with an average well yield of 24 gpm. Wells with central storage tanks, pipelines, and watering troughs provide the most reliable source of water. Catchments also provide an adequate source of water if they are properly maintained.

NAVAJO COUNTY, ARIZONA

Black Mesa (BLM)

A small portion of this study area lies within Coconino County, but the following discussion relates to the total study area.

Water supplies in this area are short and spotty. There is a need for more wells and the installation of storage tanks, distribution pipelines, and watering troughs. There are presently 88 livestock wells within the area, but 6 of these have gone dry or have been abandoned. The average depth of the wells is about 600 feet with an average flow of 14 gpm. Artificial catchment basins, properly installed and protected, and horizontal wells are possible alternative sources of livestock water.

Canyon Diablo (CDI) (See write-up under Coconino County, page 3-9.)

Chevelon (CHV) (See write-up under Coconino County, page 3-9.)

Holbrook (HOL)

Moenkopi Formation is the dominant geologic formation in the Holbrook area. Quantity and quality of water are generally good, except for groundwater in the area north of the river which is high in TDS. Groundwater to the south of the river is available at reasonable depths and furnishes a reliable source of water. (See Depth to Groundwater Map, following this page).

Surface water is of good quality with low TDS. Due to sandy soils and fractured rock formations, however, good pond sites are limited. Although some seasonal ponds can be built, wells with associated pipelines and drinking systems appear to be the best solution. Artificial catchments can also be used with good success.

Hopi (HOP)

Similar to the BLM Area, a portion of this study area is located within Coconino County, but the following discussion is referenced to the total water use area.

There have been 118 wells developed for livestock on reservation lands within this area. Forty-six of these, however are dry or have been abandoned. The average well depth is 177 feet with an average yield of 11 gpm. The eastern part of the reservation(s) has a fair but scattered water supply. The water supply for the western half is poor and very sparse. Additional wells, plus large central storage tanks with pipelines and drinkers are needed to relieve the water shortage. Earth ponds are not satisfactory in this area. Some of the more broken canyon country might lend itself to horizontal wells.

On non-reservation lands, the range consists primarily of badlands and associated breaks. Both water quantity and quality vary greatly. Usually groundwater quality is very poor, having high mineral content. (See Groundwater Availability Map, following page 5-22, Section 5.) Most people living within subdivisions carry water needed for domestic purposes. Sediment loads are a problem. In order to ensure good water quality, the most feasible alternative for increasing livestock water is the development of artificial catchments. Storage volumes for ordinary stock ponds must be large in order to provide carryover storage during periods of little or no flow.

Puerco-Zuni (PRZ) (See write-up under Apache County, page 3-8.)

Snowflake (SNO)

This area can be subdivided into two separate regions along the national forest boundary. In the area to the south of the forest boundary, i.e., within the national forest, groundwater is variable and deep (600-800 feet). Water quality, however, is good. Sediment loads are moderate. Pond sites are limited, but some good pond sites are still available in the area. The best solution for additional supplies would be year-round stock ponds.

The area to the north of the forest boundary is made up of the Moenkopi Formation. Quantity and quality of water are good. Groundwater is available at reasonable depths and is of good quality. Surface water is good with low TDS. Stock ponds and artificial catchments can be used with good success in this portion of the study area.

White Mountain (WHM) (See write-up under Apache County, page 3-8.)

Carrizo Wash (CAR)

This water use area lies mostly in Catron County with a small, northern part of the area lying in Valencia County. Pie Town has a public water supply system; the rest of the rural population is self-supplied.

For livestock water, this area has a higher proportion of wells and appurtenances and a lower proportion of ponds when compared to the New Mexico totals (Table 3-1). Comparing existing to the recommended number of facilities (Table 3-5), shows the Catron County portion to be slightly better watered than the New Mexico averages; while the Valencia County portion is among the least adequately watered.

In the northern half of this water use area, the estimated well yield is from 25 to 100 gallons per minute (gpm) and the general depth to ground water is 200 feet or less. In the southern half, the estimated yield is 25 gpm or less and the general depth ranges from 200 to 500 feet; the deeper depths are associated with the more mountainous areas found in the southern half.

Zuni (ZUN)

About two-thirds of the Zuni Water Use Area lies within Valencia County, and a third lies within McKinley County. Ramah has a public water supply system, while the rest of the rural population is self-supplied.

The area has about the same proportion of the different types of livestock watering facilities as the New Mexico totals (Table 3-1). Table 3-5 shows the McKinley County portion to be the best watered of the New Mexico portion of the Basin, while the Valencia County portion is again among the least adequately watered.

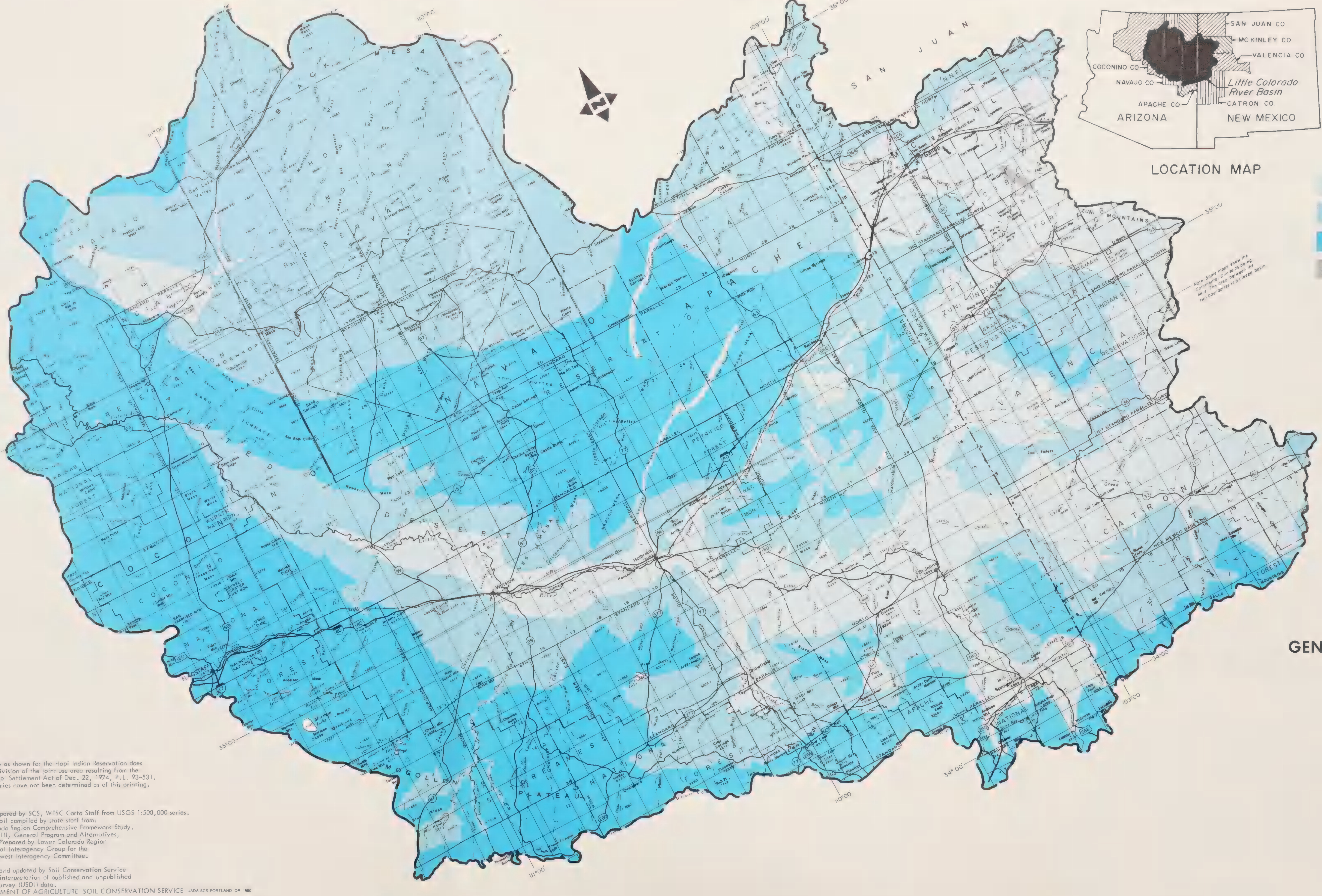
In approximately 90 percent of the area, potential well yields of 25 to 100 gpm can be expected. In a small area along the Nutria River upstream from its confluence with the Zuni River, yields of 100 to 500 gpm can be expected. Other small areas where yields are 25 gpm or less are as follows:

1. An area south of Zuni extending into Valencia County, and east of Ojo Caliente.
2. An area along the Continental Divide in north-central Valencia County; rock outcrops make water difficult to find and drilling expensive.
3. An area in McKinley County around McGaffey; rock outcrops also appear in this area.

In approximately 80 percent of the water use area, the general depths to water are 200 feet or less. In the other 20 percent, the depths range from 200 feet to greater than 500 feet.

Upper Puerco (UPR)

The Upper Puerco Water Use Area lies almost entirely in McKinley County; about one percent lies in San Juan County. The rural communities of Allison, Fort Wingate, Iyanbito, and Mariano Lake have public water supply systems; the rest of the rural population is self-supplied.



LOCATION MAP

LEGEND

- Less than 200
- 200 to 500
- More than 500
- Areas of outcrop of granite, quartzite, rhyolite, large masses of intrusive rocks, and metamorphosed sedimentary rocks. The water table in these areas is likely to be discontinuous. Locally the rocks are dry. Limited quantities of water are present, locally, where the rocks are fractured or weathered, and in sand and gravel deposits of major stream valleys. The depth to water, where water is present, is commonly less than 100 feet below the land surface.

Depth to water, in feet below land surface

GENERAL DEPTH TO GROUNDWATER

LITTLE COLORADO RIVER BASIN

ARIZONA AND NEW MEXICO

APRIL 1980

10 0 10 20 MILES

SCALE 1:1,000,000

Note:
The boundary as shown for the Hopi Indian Reservation does not reflect division of the joint use area resulting from the Navajo - Hopi Settlement Act of Dec. 22, 1974, P.L. 93-531. Final boundaries have not been determined as of this printing.

Source:
Base map prepared by SCS, WTSC Carto Staff from USGS 1:500,000 series. Thematic detail compiled by state staff from: Lower Colorado Region Comprehensive Framework Study, Appendix XVIII, General Program and Alternatives, June 1971. Prepared by Lower Colorado Region State - Federal Interagency Group for the Pacific Southwest Interagency Committee.

Data revised and updated by Soil Conservation Service personnel by interpretation of published and unpublished Geological Survey (USDI) data.

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For livestock water, this area has a higher proportion of ponds and lower proportion of wells with appurtenances compared to the New Mexico totals (Table 3-1). The small San Juan County portion is adequately watered from its live streams, springs, and natural ponds. Table 3-5 shows the McKinley County portion to be slightly better watered than the New Mexico averages.

Potential well yields of 25 to 100 gpm can be expected in approximately 90 percent of the area. Wells will potentially yield 25 gpm or less in a small area in the southeast portion of the water use area. A small area around Gallup and extending to the north will potentially yield 100 to 500 gpm. General depths to groundwater range up to 500 feet, but in approximately 80 percent of the area, groundwater may be obtained at depths of 200 feet or less.

PROBLEMS

Some of the major problems in the development of adequate water supplies for rural domestic and livestock purposes include: availability and depth to groundwater, poor water quality, distribution of population and/or watering facilities, sedimentation, evaporation and seepage losses, and high cost of development.

Water for rural domestic purposes is scarce. Because of the scattered nature of the rural population, the development of central water supply systems is generally not practical. However, in selected communities where organizational structure is adequate, some central distribution systems are being planned and installed. The individual family also has difficulty in developing it's own water supply. This is due to the semiarid nature of the Basin, the depth to groundwater, and the problem of poor water quality. These problems are especially acute on the Indian reservations.

Except for a central corridor along the Little Colorado River and for the southern and southeastern halves of Apache and Navajo Counties, respectively, the depth to groundwater in the Arizona portion of the Basin exceeds 500 feet. Along the central corridor of the river there is a strip of land with estimated depths to water of less than 200 feet.

In New Mexico, the depth to water is generally in the range of 500 feet or less. (See Depth to Water Map following page 12). Generally, as the depth to water increases, the cost of development also increases.

In developing surface water resources, evaporation and sedimentation are the two major problems encountered. Vegetation in many areas is sparse; and with the erosive nature of the soils, newly constructed reservoirs are soon filled with sediment, or their capacities greatly reduced. The sediment laden waters may also become so muddy at times that they are unfit for livestock consumption.

It seems significant that the amount of water consumed by livestock from the ordinary reservoir is only a small fraction of the total flow in the washes; most of the stored water is lost by evaporation or seepage. Many times the evaporation and seepage result in complete water loss from the reservoir. "In order to provide carryover, the tendency for the stockman has been to make their reservoirs large, thus, creating great surface areas and thereby increasing losses of water by evaporation and seepage " (3). The estimated evaporation losses from stock ponds, by water use areas, are shown in Table 3-2, page 3-6.

"An important problem in water conservation is to minimize waste by permitting the surplus waters to flow downstream for the benefit of other users and for useful native vegetation. The solution of this problem depends largely on adequate data on runoff and sedimentation in the "dry" washes in the semi-arid and arid parts of the basin.... Records demonstrate that there is generally little need for a reservoir to have a capacity greater than that necessary to store the mean annual runoff (plus the required sediment storage). Uplike an irrigation reservoir, the performance of a stockwater reservoir is dependent on depth of water rather than on capacity." (3) Guidelines for proportioning stock ponds are available from the Soil Conservation Service.

Another major problem related to rural domestic and livestock waters is that of distribution. Although there may be an adequate number of watering facilities within an area, these facilities may not be properly spaced. This is especially true with respect to livestock ponds where site availability determines placement to a large extent. Obstruction such as fences; or natural barriers such as ridges, steep grades, canyons, etc., may prevent the proper use of nearby stock ponds or other watering facilities. The dependability of stock ponds is also questionable because many go dry during long periods of little or no runoff. The increased use of wells, storage tanks, pipelines and watering trough installations will help to alleviate the problem under future development.

The high cost of development is probably the main obstacle to increasing the present water supplies for either rural domestic or livestock purposes. For example, the estimated cost of drilling a 6-inch well to a depth of approximately 600 feet, which is typical in a large part of the Basin, is about $18,000. Of course, for a larger size or deeper well, the cost would increase proportionately. The cost of development of stock ponds and artificial catchment basins also are relatively high. Thus, the problems of providing an adequate water supply for either rural domestic or livestock purposes are many and varied; and because of the high cost; solutions to these problems are not easily found.

PROJECTED CONDITIONS

The projected conditions for rural domestic water supplies does not appear to be much different from those under present conditions, although a few central water supply systems are being installed. Also, because of the high cost of development, individual families generally are not able to develop their own supplies.

The picture for livestock water supplies, however, is somewhat different. With the introduction of artificial watersheds, and the increased use of wells, pipelines, and watering trough types of installations, the possibility of increasing livestock water supplies has been improved. The continued and increased use of the standard stock pond is also a means of ensuring an adequate water supply for livestock in some areas. The ranchers in the southern half of Apache County still favor the stock pond as the ultimate source for stockwater.

In Arizona, however, there is a need to obtain authorization from the Arizona Department of Water Resources before surface waters can be developed and utilized. In the past this authorization may have been ignored. In the future, obtaining this authorization may be difficult. This results from the recent passage of two new water rights registration acts by the Arizona Legislature.

The first act is the "Water Rights Registration Act of 1974." This act required that all claims for water rights, adjudicated under the June 12, 1919 Water Rights

Law, to be refiled or registered with the Arizona Department of Water Resources. A total of 19,662 such claims were filed with the Department.

The second act affecting stock pond construction is the "Stock Pond Registration Act of 1977." This act made all stock ponds (with a capacity of 15 acre-feet or less) constructed between June 12, 1919 and August 29, 1977 legal. This is true, although the stock ponds may have been constructed illegally, when the owner did not obtain a permit as required by the June 12, 1919 Water Rights Law. For this reason, water rights obtained under this act are subject to prior appropriations made under previous water laws. Under the 1977 Act, there were a total of 15,353 stock ponds registered within the state.

Although the 1974 and 1977 acts did not change the water law with regard to obtaining permits for the construction of new stock ponds, they did make the public more aware of the procedures; and increased the possibility of protest in the granting of new water rights because of a better informed public.

New Mexico is generally aligned with other western states in the application of the doctrine of prior appropriation, but its appropriation statutes do not apply to stock ponds which do not exceed 10 acre-feet in capacity. Stock pond owners, however, are responsible at all times for any detriment or damage to prior water rights which may result from the construction and storage of water in such ponds.

The number of watering facilities for livestock in the Basin has been projected to increase at a rate of about 40 to 50 per year. Increases will probably come from wells and their appurtenances while ponds will remain about the same or decrease slightly.

NEEDS BY TIME FRAME

The total water supply needs for rural domestic and livestock waters by time frame are given in Tables 3-3 and 3-4, respectively. Table 3-3, for rural domestic waters, was developed using average use rates, in gallons-per-capita-day (gpcd), together with the estimated present and projected rural populations. The water use rates were estimated at 50 gpcd for 1975, 55 gpcd for 1990, 60 gpcd for 2000, and 65 gpcd for 2020. These use rates were developed during the Lower Colorado Region Comprehensive Framework Study and are published in Appendix XI, Municipal and Industrial Water Supply, P. XI-79. The population estimates were developed by the Economics and Statistics Service during the present study.

Increases in population are projected for most rural areas of the Basin, except McKinley County, New Mexico. In McKinley County, a decrease in the rural population is expected. This is a result of migration of people from the rural areas into the City of Gallup.

The numbers of livestock within the Basin were also developed by the Economics and Statistics Service. These were first estimated using Crop and Livestock Reporting Service or Census of Agriculture Data for the total county areas comprising the Basin. Estimates were then made, based on judgment of informed individuals, of that portion of the total livestock numbers within the Basin and within each of the water use areas. The amount of water used by livestock, not including swine, was then estimated based on a weighted consumptive water use rate (AC-FT/AU) and the number of animal units (AU) within each water use area. The water used by swine was calculated separately, based on their estimated number. (See footnote at bottom of Table 3-4.)

Future livestock water requirements in Arizona were estimated based on the water use rate and projected livestock numbers as they might be modified by grazing management systems. The projected increases were based on a continuation of the "ongoing" program. With the "ongoing" program, only minor increases (about 10 percent by 2020) are expected in Arizona. In New Mexico, projections of livestock water requirements were derived from county data found in the New Mexico Water Resources Assessment. To disaggregate county data to the water use areas, "livestock water use per unit area" was assumed to be equal.

Applying the following guidelines for management and distribution of livestock, the total number of livestock watering facilities needed were determined (Table 3-5): 1) On gentle slopes cattle should not have to travel more than 1-mile or less than 1/2-mile to water; 2) On steeper slopes they should not have to travel more than 1/2-mile nor less than 1/4-mile. Since it was assumed that the total range is presently being used and will continue to be used throughout the study time frame, the required number of watering facilities would remain the same. The net needs by time frame were then estimated based on the difference between the total required number of watering facilities and the number presently installed plus those estimated to be installed under the "ongoing" program within each time frame. Based on records of past years and judgement of informed individuals, livestock producers will install, under the "ongoing" program, 40 to 50 watering facilities per year.

ALTERNATIVE SOURCES OF SUPPLY

The alternatives for increasing the water supply for rural domestic purposes are very limited. Except for springs, the use of surface water supplies for rural domestic purposes is virtually non-existent. There is very little prospect that this situation will change in the projected future. Thus, the major alternative for supplying water for rural domestic purposes is groundwater. A general indication of the availability of groundwater together with an indication of its quality, is shown on the map entitled, "Availability of Groundwater for Irrigation, Municipal, or Industrial Use in the Little Colorado River Basin, Arizona and New Mexico" (see map(s) following page 5-22, Section 5). This map(s) can be used as a guide by individuals or community planners to determine the general locations of groundwater for possible development, but it must be recognized that detailed investigations will be needed in order to make sound decisions concerning its actual development.

The "Groundwater Availability Map" can also be used as a guide in locating possible groundwater sources for livestock. The development of wells with associated storage tanks, pipelines, and properly located drinkers is one of the more promising alternatives for increasing livestock water supplies. Horizontal wells may be a good economic alternative in hilly or mountainous areas where intermittent seeps occur. The use of artificial catchments is also becoming more competitive with other sources. Catchments are especially beneficial in areas of limited precipitation and/or runoff.

Development of springs and increasing the number of standard stock ponds are two other recognized alternatives for increasing water supplies for livestock. Stock ponds, however, must be selected with care to ensure that adequate runoff is available to fill the ponds. A site with a high depth to storage ratio is preferred, since the performance of a stock-water reservoir is more dependent upon its depth rather than on its capacity. Sites should also be selected that will

TABLE 3-3: ESTIMATED RURAL DOMESTIC WATER REQUIREMENTS
LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO
(CONTINUED)

WATER USE AREA	RURAL POPULATION				WATER DEMANDS			
	1975	1990	2000	2020	1975	1990	2000	2020
					Ac. Ft./Yr.			
Apache Co., Arizona								
Chinle Valley (CHN)	9,800	10,650	12,400	12,600	549	656	833	917
Concho (CON) 1/								
Puerco-Zuni (PRZ)	90	220	230	280	5	14	15	20
St. Johns (STJ)	250	450	590	750	14	28	40	55
White Mountains (WHM)	200	300	350	570	11	18	24	41
Subtotal	10,340	11,620	13,570	14,200	579	716	912	1,033
Coconino Co,. Arizona								
Black Mesa (BLM)	1,000	1,100	1,200	1,300	56	68	81	95
Bodaway Mesa (BOD)	980	1,600	2,010	2,670	55	99	135	194
Canyon Diablo (CDI)	200	300	400	600	11	18	27	44
Chevelon (CHV)	100	120	190	230	6	7	13	17
Hopi (HOP)	1,120	1,700	2,150	2,750	63	105	144	200
Kaibito Plateau (KAI)	2,200	3,040	3,830	5,300	123	187	257	386
San Francisco Peaks (SFP)	3,000	7,080	9,500	13,700	168	436	638	997
Tuba City (TUB)	1,450	2,550	3,250	3,100	81	157	218	226
Subtotal	10,050	17,490	22,530	29,650	563	1,077	1,513	2,159
Navajo Co., Arizona								
Black Mesa (BLM)	8,940	14,700	18,150	24,100	500	905	1,220	1,754
Canyon Diablo (CDI)	100	200	250	300	6	12	17	22
Chevelon (CHV)	300	480	550	780	17	30	40	57
Holbrook (HOL)	1,000	1,400	1,660	2,200	56	86	112	160
Hopi (HOP)	6,100	9,600	12,100	15,700	342	591	813	1,143
Puerco-Zuni (PRZ)	20	50	100	150	1	3	7	11
Snowflake (SNO)	1,200	1,600	1,870	2,400	67	99	126	175
White Mountains (WHM)	300	450	510	380	17	28	34	28
Subtotal	17,960	28,480	35,190	46,010	1,006	1,754	2,369	3,350
TOTAL ARIZONA	38,350	57,590	71,290	89,860	2,148	3,547	4,794	6,542

1/ Total population for this WUA is included under the "Municipal and Industrial Water Supply Section," Section 2.

TABLE 3-3: ESTIMATED RURAL DOMESTIC WATER REQUIREMENT
LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO
(CONTINUED)

WATER USE AREA	RURAL POPULATION				WATER DEMANDS			
	1975	1990	2000	2020	1975	1990	2000	2020
					---------Ac. Ft./Yr.---------			
Catron Co., New Mexico								
Carrizo Wash (CAR)	150	130	150	150	8	8	10	11
Subtotal	150	130	150	150	8	8	10	11
McKinley Co., New Mexico								
Upper Puerco (UPR)	16,450	7,800	6,900	4,000	921	481	464	291
Zuni (ZUN)	620	300	200	100	35	18	13	7
Subtotal	17,070	8,100	7,100	4,100	956	499	477	298
Valencia Co., New Mexico								
Carrizo Wash (CAR)	50	50	50	100	3	3	3	7
Zuni (ZUN)	950	950	950	1,900	53	59	64	139
Subtotal	1,000	1,000	1,000	2,000	56	62	67	146
TOTAL NEW MEXICO	18,220	9,230	8,250	6,250	1,020	569	554	455
TOTAL BASIN	56,570	66,820	79,540	96,110	3,168	4,116	5,348	6,997

TABLE 3-4: ESTIMATED LIVESTOCK WATER REQUIREMENTS
LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO

WATER USE AREA	ESTIMATED WATER REQUIREMENTS 1/			
	1975 (Ac. Ft.)	1990 (Ac. Ft.)	2000 (Ac. Ft.)	2020 (Ac. Ft.)
Apache Co., Arizona				
Chinle Valley (CHN)	134	142	145	150
Concho (CON)	68	70	73	75
Puerco-Zuni (PRZ)	249	261	270	280
St. Johns (STJ)	101	106	110	113
White Mountains (WHM)	122	127	131	136
Subtotal	674	706	729	754
Coconino Co., Arizona				
Black Mesa (BLM)	19	20	20	20
Bodaway Mesa (BOD)	11	11	11	11
Canyon Diablo (CDI)	27	28	29	28
Chevelon (CHV)	19	20	20	20
Hopi (HOP)	19	19	20	19
Kaibito Plateau (KAI)	11	11	11	11
San Francisco Peaks (SFP)	39	39	40	39
Tuba City (TUB)	11	11	11	11
Subtotal	156	159	162	159
Navajo Co., Arizona				
Black Mesa (BLM)	183	193	199	205
Canyon Diablo (CDI)	7	8	8	8
Chevelon (CHV)	66	69	71	73
Holbrook (HOL)	84	89	91	94
Hopi (HOP)	250	262	269	278
Puerco-Zuni (PRZ)	22	24	24	25
Snowflake (SNO)	196	226	246	268
White Mountain (WHM)	15	15	16	16
Subtotal	823	886	924	967
TOTAL ARIZONA	1,653	1,751	1,815	1,880

TABLE 3-4: ESTIMATED LIVESTOCK WATER REQUIREMENTS
LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO
(CONTINUED)

WATER USE AREA	ESTIMATED WATER REQUIREMENTS 1/			
	1975 (Ac. Ft.)	1990 (Ac. Ft.)	2000 (Ac. Ft.)	2020 (Ac. Ft.)
Catron Co., New Mexico				
Carrizo Wash (CAR)	180	192	199	214
Subtotal	180	192	199	214
McKinley Co., and Valencia Co., New Mexico				
Upper Puerco (UPR)	121	112	115	133
Zuni (ZUN)	214	227	238	288
Subtotal	335	339	353	421
TOTAL NEW MEXICO	515	531	552	635
TOTAL BASIN	2,168	2,282	2,367	2,515

1/ Estimated water requirements were based on number of animal units and a weighted water use coefficient using 12 gal/day/AU for cattle, 5 gal/day/AU for sheep and 13 gal/day/AU for horses. The ratio of the various animal species in each area was based on census of Agriculture Data. Water requirements for hogs and pigs, which are included in total water requirements, were calculated separately and are based on 3 gal/day/animal.

TABLE 3-5: LIVESTOCK WATERING FACILITIES NEEDS
LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO

WATER USE AREA	RECOMMENDED NUMBER	1975 EXISTING (No.)	1975 NEEDS (No.)	1990 EXISTING (No.)	1990 NEEDS (No.)	2000 EXISTING (No.)	2000 NEEDS (No.)	2020 EXISTING (No.)	2020 NEEDS (No.)
Apache Co., Arizona									
Chinle Valley (CHN)	1,042	295	747	318	724	334	708	350	692
Concho (CON)	155	116	39	125	30	131	24	137	18
Puerco-Zuni (PRZ)	1,435	491	944	530	905	557	878	608	827
St. Johns (STJ)	387	278	109	300	87	315	72	330	57
White Mountains (WHM)	586	511	75	552	34	582	4	586	-
Total Co.	3,605	1,691	1,914	1,825	1,780	1,919	1,686	2,011	1,594
Coconino Co., Arizona									
Black Mesa (BLM)	744	257	487	288	456	314	430	341	403
Bodaway Mesa (BOD)	357	41	316	42	315	43	314	44	313
Canyon Diablo (CDI)	707	643	64	656	51	674	33	693	14
Chevelon (CHV)	581	263	318	268	313	275	306	282	299
Hopi (HOP)	399	100	299	112	287	122	277	133	266
Kaibito Plateau (KAI)	227	93	134	95	132	98	129	101	126
San Francisco Peaks (SFP)	1,027	525	502	536	491	551	476	566	461
Tuba City (TUB)	300	184	116	188	112	193	107	198	102
Total Co.	4,342	2,106	2,236	2,185	2,157	2,270	2,072	2,358	1,984
Navajo Co., Arizona									
Black Mesa (BLM)	2,154	578	1,576	649	1,505	706	1,448	768	1,386
Canyon Diablo (CDI)	26	15	11	15	11	16	10	16	10
Chevelon (CHV)	447	323	124	362	85	388	59	414	33
Holbrook (HOL)	311	266	45	299	12	311	-	311	-
Hopi (HOP)	1,339	662	677	743	596	808	531	882	457
Puerco-Zuni (PRZ)	330	74	256	80	250	84	246	92	238
Snowflake (SNO)	301	265	36	297	4	301	-	301	-
White Mountains (WHM)	97	88	9	95	2	97	-	97	-
Total Co.	5,005	2,271	2,734	2,540	2,465	2,711	2,294	2,881	2,124
TOTAL ARIZONA	12,952	6,068	6,884	6,550	6,402	6,900	6,052	7,250	5,702

TABLE 3-5: LIVESTOCK WATERING FACILITIES NEEDS
LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO
(CONTINUED)

WATER USE AREA	RECOMMENDED NUMBER	1975 EXISTING (No.)	1975 NEEDS (No.)	1990 EXISTING (No.)	1990 NEEDS (No.)	2000 EXISTING (No.)	2000 NEEDS (No.)	2020 EXISTING (No.)	2020 NEEDS (No.)
Catron Co., New Mexico									
Carrizo Wash (CAR)	1,303	941	362	1,006	297	1,081	222	1,081	222
Total Co.	1,303	941	362	1,006	297	1,081	222	1,081	222
McKinley Co., New Mexico									
Upper Puerco (UPR)	886	626	260	694	192	771	115	771	115
Zuni (ZUN)	456	347	109	386	70	430	26	430	26
Total Co.	1,342	973	369	1,080	262	1,201	141	1,201	141
San Juan Co., New Mexico									
Upper Puerco (UPR)	15	15	-	15	-	15	-	15	-
Total Co.	15	15		15		15		15	
Valencia Co., New Mexico									
Carrizo Wash (CAR)	93	36	57	38	55	40	53	40	53
Zuni (ZUN)	767	307	460	323	444	342	425	342	425
Total Co.	860	343	517	361	499	382	478	382	478
TOTAL NEW MEXICO	3,520	2,272	1,248	2,462	1,058	2,679	841	2,679	841
TOTAL BASIN	16,472	8,340	8,132	9,012	7,460	9,579	6,893	9,929	6,543

minimize seepage losses. For example, soils with high clay content usually have better water holding capabilities than those consisting basically of sandy materials. Also, prior appropriation of water may limit the development of stock ponds as an alternative source of livestock water, especially in Arizona.

Specific recommendations of alternatives to be used in each of the designated water use areas were given under the "Present Water Supply" section of this report. Because of the general nature of the report, further expansion of these recommendations is not warranted at this time.

USDA AND OTHER PROGRAMS

Many programs exist within the U.S. Department of Agriculture that can provide technical and financial assistance to public entities and individuals. Certain conditions must be met to qualify for assistance; each agency can furnish the specific conditions and program details. Several USDA agencies have special programs available during times of disaster such as drought or flood. Some agencies which provide assistance include the Soil Conservation Service (SCS), Forest Service (FS), Agricultural Stabilization and Conservation Service (ASCS), and Farmers Home Administration (FmHA).

SOIL CONSERVATION SERVICE

SCS can provide engineering, geologic, and range management expertise to investigate, design, layout, and supervise construction of livestock water facilities. The SCS provides assistance to land users through local conservation districts; this assistance is coordinated with the land users' conservation plan. Often, in cooperation, SCS provides technical assistance while the ASCS provides financial assistance for livestock water development.

AGRICULTURAL STABILIZATION AND CONSERVATION SERVICE

The Agricultural Conservation Program administered by the ASCS provides cost sharing of 50 to 75 percent for livestock water development. In the Little Colorado River Basin, cost can be shared for:

1. Construction or deepening of wells
2. Development of springs and seeps
3. Dugouts, pit tanks, ponds or dams
4. Installing pipelines, storage facilities, cisterns, and artificial watersheds

Single items may be cost shared or cost sharing may be scheduled over a period of years and may extend to several types of livestock water development. Land users may request assistance individually, or two or more may participate in a "pooling agreement."

FOREST SERVICE

On national forest lands under permit for grazing, the Forest Service can share costs for livestock water development with stockmen. The Forest Service can issue permits for the development of water resources on national forest lands and the transmission of water to adjoining lands for either rural domestic or livestock use.

FARMERS HOME ADMINISTRATION

FmHA provides credit and management aid to people in rural areas. Most FmHA programs require that a borrower be unable to obtain needed funds from other sources at reasonable rates and terms. FmHA loan programs include:

1. Water and Waste Disposal Loans and Grants -- loans are available to public entities for rural domestic water development. Priority is given to areas with less than 5,500 people. Grants, up to 50 percent, may be available for the most financially needy of rural communities.

2. Farm Ownership Loans -- eligible operators of family farms may use funds for many eligible items, including well drilling and otherwise improving water supply systems for home and livestock use.

3. Grazing Association Loans -- eligible associations of family farmers and ranchers may use funds for specified items, including livestock water development.

OTHER PROGRAMS (2)

The discussion in Section 4,"Municipal and Industrial Water Supply," under "Other Programs", also applies to public entities who wish to develop rural domestic water. Examples of public entities include: municipalities, counties, special purpose districts, Indian tribes, and corporations not operated for profit.

The Bureau of Land Management (BLM) and Bureau of Indian Affairs (BIA), both within the Department of Interior, are concerned with the development of livestock water. BLM developes water on its lands for consumption by livestock and to better distribute grazing. BLM has done some livestock water development in Catron County, but none has been done in Valencia or McKinley Counties. Within the Little Colorado River Basin of the latter two counties, BLM lands are more scattered and are of less area than in Catron County. BIA supports many programs on Indian lands. For example, the Pueblo of Zuni has adopted a "Range Code." The code will aid the Zuni people in achieving maximum livestock production while maintaining or improving the range condition (8). Development of livestock water, a necessary part of the total range management plan, should also prove useful in distributing grazing more evenly.

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SECTION 4

DEVELOPMENT OF SURFACE WATER RESOURCES

SECTION 4

Development of Surface Water Resources

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SECTION 4

DEVELOPMENT OF SURFACE WATER RESOURCES

INTRODUCTION

This report presents data on the existing storage and possible future development of surface water within the Little Colorado River Basin.

The identification of problems and needs in the initial phase of this river basin study listed a shortage of surface water development for the purposes of irrigation, flat water recreation, and fish and wildlife as areas of public concern. Consequently, the investigation of additional water development projects, primarily storage projects, was included as a study objective.

The primary thrust of this study was in determining the potential for additional irrigation reservoirs or recreation reservoirs in the forested, southern part of the Basin. It became increasingly apparent as the study progressed and more information became available that a lot of work had been done in the past on investigating reservoir sites by the Arizona Game and Fish Department, the U.S. Bureau of Reclamation, the Soil Conservation Service, consulting engineering firms, and others. Many of the sites investigated were ruled unfeasible for various reasons while others were considered feasible but were never constructed. Conflicts over water rights were, and still are, a major reason why construction has never occurred at many sites.

This report is essentially divided into three sections: (1) a discussion of the sites considered by USDA during the course of this study; (2) a discussion of other surface water development proposals and investigations; and (3) an inventory of existing reservoirs and lakes.

The sites considered by USDA include 26 sites in Arizona that may have potential for future construction (see Table 4-1), and 14 sites in Arizona that USDA considers to be unfeasible (see Table 4-2). This report does not include any data on new sites in New Mexico. USDA did not investigate any sites on the Navajo Indian Reservation because the Navajo Tribe has completed a preliminary reconnaissance study of potential sites in cooperation with the U.S. Bureau of Reclamation. The results of their study have not been published as of this writing.

The data on other surface water development proposals and investigations is included for future reference. Information on many of these sites has never been readily available to all possible users; the results of investigations conducted being available only from the files or memory of individuals from the various agencies. The data presented here represents an attempt by USDA to summarize the status of the proposed developments. The locations of proposed developments, including those studied by USDA,are shown on "Proposed Development of Surface Water Resources Map" following this page.

The inventory of existing reservoirs and lakes was generated as basic data and is given in Table 4-3, and the site locations are shown on "Existing Reservoirs and Lakes Map" following page 4-62.

PREVIOUS INVESTIGATIONS

Investigations on the improvement of existing reservoirs and the construction of new reservoirs have been conducted by several agencies. These investigations range from site specific studies to basin-wide reconnaissance level studies.

The Arizona Game and Fish Department has conducted numerous studies within the Basin on the potential for construction of fish and wildlife reservoirs. These studies were conducted both by Department personnel and consultants. The Game and Fish Department was very active in the 1950's and 1960's in pursuing new reservoir developments and their efforts led to the successful completion of many reservoirs, including; Knoll Lake, Chevelon Canyon, Black Canyon, Bear Canyon, and others. This effort resulted in part from legislative enactment of the State Lake Improvement Fund (1960), which utilizes a license fee on boat registrations for lake improvements and the construction of new reservoirs. Construction has slowed in recent years and priorities have shifted to the improvement of existing sites rather than new construction. This has occurred for several reasons: the national emphasis prevalent in the 1960's about satisfying recreational demand has abated; many feasible sites cannot be developed because of conflicting water rights; the trend is toward "urban lakes", rather than remote sites, to satisfy recreational demand near population centers; the preservation of wildlife habitat is often favored over construction of recreation reservoirs; and a lot of the demand has been met by lakes that have been constructed.

The Bureau of Reclamation has conducted several reconnaissance studies that propose the development of reservoirs in the Basin for irrigation and municipal and industrial purposes. These are summarized in the "Other Surface Water Development Proposals and Investigation" section of this report.

SCOPE OF INVESTIGATIONS

This is a reconnaissance level study. Physical design and cost data were developed to the extent necessary to evaluate the potential for such purposes as recreation, irrigation, fish and wildlife, and erosion and sediment control.

It should not be inferred from the plans that all sites are entirely feasible. There may be physical, legal, financial, or institutional restraints that are unrecognized. The proposals are presented solely to provide a basis for future discussion and study, however, any restraints or conflicts known to exist at a particular site are discussed.

This study began with an assembly of background data on reservoir sites that have been proposed in the past. This effort included a literature review of reports prepared by other agencies, a review of the applications for reservoir construction on file with the Office of Dam Safety, Arizona Department of Water Resources (formerly the Arizona Water Commission), consultations with the Arizona Game and Fish Department, a review of projects proposed by the Little Colorado River Plateau Resource Conservation and Development Area, discussions with personnel in the Soil Conservation Service Field Offices in Springerville, Holbrook, and Flagstaff, and discussions with other agencies and individuals.

An inventory was made of all existing reservoirs and lakes within the Basin. This inventory served as a tool in the selection of potential sites. The inventory, in combination with an analysis of yield data, was used to eliminate several watersheds from further study because of insufficient water yield to sustain additional storage.

Maps and aerial photographs were used to select areas for further study. A field reconnaissance was made of potential sites by an engineer and geologist. They were accompanied by other disciplines as the need required.

LOCATION MAP

LEGEND

POTENTIALLY FEASIBLE SITES STUDIED BY USDA

- Benny Creek
- Bigelow Crossing
- Davis Creek
- Escudilla
- Sheep Springs
- Sizer Knoll
- South Fork Spring
- Sunnyside
- Twenty Four Draw
- Barbershop Canyon
- Beaver Canyon
- Buck Springs
- Clark Springs
- Dane Canyon
- Gentry Canyon
- Jacks Canyon
- Leonard Canyon
- Nutrioso (4 sites)
- Sawmill Springs
- Scotts Reservoir
- Turkey Canyon
- Yeager Canyon
- Long, Whipple, and Little Mormon Lake
- Aguirre Wash
- Coyote Creek
- Youngs Canyon Tank

UNFEASIBLE RESERVOIRS STUDIED BY USDA

- Baca Cemetary
- Benny Creek (Lower)
- Bluff
- Chavez Canyon
- Cottonwood Upper
- Dipping Vat
- Ellsworth Point
- Gillespie Flat
- Grapevine Canyon
- Hall Creek
- Hoxworth Springs
- Indian Hill
- Turkey
- Turkey Track

OTHER DEVELOPMENT PROPOSALS*

U. S. Bureau of Reclamation

41. Black River-Springerville-St. Johns Project (M&I Reservoir)
- Mogollon Mesa Project (Wilkins Dam)
- Winslow-Holbrook Project (Wildcat Dam)
44. Gallup Project (Houck Dam)
45. Snowflake Project (Shumway Dam)
46. Yellowhouse Project (Yellowhouse Dam & Black Rock Dam)

U.S.D.A. Public Law 566 Projects

- Cottonwood Wash

Little Colorado River Plateau RC&D Proposals

48. Ganado Reservoir
49. Hidden Lake
50. Hopi Waterbased Recreation
51. Joseph City Irrigation Reservoir
52. Trout Lake
53. Woodruff Lake
54. Woodruff Reservoir

Flagstaff M&I Water Supply Proposals

- Tremaine - Soldier Annex Project
- Anderson Mesa Project
57. Mormon Lake

Miscellaneous Proposals

- Ashurst Lower
59. Double Cabin
- Ellsworth Reservoir
61. Empire Lake
- Mineral
- Pinedale
- Rim Dam
- Travertine
- Vernon (4 sites)

*Note: *Several of these sites are unfeasible and have been abandoned. They are listed for reference only. Refer to the report for a discussion on the status of individual sites.*

15020004 Hydrologic Unit Code, U.S. Water Resources Council

PROPOSED DEVELOPMENT OF SURFACE WATER RESOURCES

LITTLE COLORADO RIVER BASIN

ARIZONA AND NEW MEXICO

AUGUST 1980

10 0 10 20 MILES

SCALE 1:1,000,000

Note:
The boundary as shown for the Hopi Indian Reservation does not reflect division of the joint use area resulting from the Navajo-Hopi Settlement Act of Dec. 22, 1974, P.L.93-531 Final boundaries have not been determined as of this printing

Source:
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series.
Thematic detail compiled by state staff.

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE USDA-SCS-PORTLAND, OR 1981

DESIGN AND COSTS

Designs were prepared from U.S. Geological Survey 7 1/2' quadrangle maps. No site surveys were conducted. Preliminary construction cost estimates were prepared based upon 1979 prices. These are preliminary estimates; firm costs can be determined only after detailed geologic and engineering investigations, and final structural designs. The construction cost figures include a percentage for contingencies. Cost estimates do not include costs for engineering and administrative services necessary for surveys, geology investigations, final design, and inspection; nor do they include costs of land required for construction and costs associated with the purchase or relocation of manmade facilities. The land ownership and anticipated relocation of facilities necessary at each site are discussed in the individual site reports.

WATER YIELD

The primary basis for determining average annual water yield at each site was the Arizona water yield map developed in 1951 by Jack Dorrah (11).[1/] The data from this map was supplemented, and often modified, by comparing conditions at a proposed site, with existing nearby reservoirs. The parameters used in this analysis included a comparison of storage at an existing reservoir with size of drainage area, topography, slope aspects, vegetal cover and type, geologic conditions, the presence of springs and other factors.

GEOLOGIC INVESTIGATIONS

A geologist made a surficial investigation of most sites to determine the amount of sediment to be trapped and any obvious geologic condition that might affect water holding capability and structural integrity. No borings were made, and subsurface conditions may vary from those discussed in this report.

ECONOMIC FEASIBILITY

This is an engineering reconnaissance study to determine physical potential. The possible sources of funding for these projects include the State of Arizona's State Lake Improvement Fund and State Water Conservation and Development Fund, the Four Corner's Regional Commission, and USDA's Agricultural Conservation Program. A favorable benefit:cost ratio is not the sole criterion for funding in these programs and the limited scope of the study did not permit economic feasibility studies.

RECREATION DEMAND

Recreation demand studies are recommended if detailed planning is done on the sites with recreation as a purpose. This subject is discussed further in the "Summary and Conclusions Regarding USDA Site Investigations" section of this report.

ENVIRONMENTAL IMPACTS

A full evaluation of environmental impacts that would result from construction is beyond the scope and intent of this report. The plans were reviewed with many specialists within USDA; including a soil scientist, biologist, soil conservationist, plant scientist, forester, archeologist, hydrologist, and others in an

1/ Numbers in parentheses refer to references listed in back of this section of the Appendix.

attempt to recognize any major environmental impacts that may occur. One site, Grapevine Canyon in Coconino County, was eliminated because of the presence of a large Indian ruin at the site. The Arizona Game and Fish Department has reviewed the site proposals. Their position on the sites classified as "potentially feasible" by USDA is either incorporated into the narrative for each individual site or is included in the footnotes for Table 4-1.

WATER RIGHTS

The limited scope of the study did not permit a complete examination of water rights. In fact, conflicts over water rights are the main reason that many feasible sites have not been developed in the past. Water right restrictions were recognized prior to the initiation of this study; however, it was decided to conduct the study under the assumption that water right conflicts would not govern the feasibility or non-feasibility of a site. The reader should not infer that any needed water rights are available, or that they may be available in the future.

The Arizona Game and Fish Department has attempted to obtain storage rights for fish and wildlife reservoirs at several sites, particularly in the White Mountain on the headwaters of the Little Colorado River above Springerville and St. Johns. These sites include Slade and Atcheson Lakes, the Sheep Springs site, Bigelow Crossing, Nutrioso Section 36 site, and possibly others. The applications have been refused upon protest by downstream users.

Title 45-172, Arizona Revised Statutes, states: "A water right may be severed from the land to which it is appurtenant or from the site of its use if for other than irrigation purposes...subject to the following limitations and conditions." "5...No application for the severance or transfer of a right to the use of water or from any watershed or drainage area which supplies or contributes water for the irrigation of lands within any irrigation district, agricultural improvement district or water users association shall be accepted for filing unless accompanied by the written consent of the governing body of such irrigation district, agricultural improvement district or water users association to the proposed application...."

Thus, the written consent of downstream users is required even if irrigated lands are purchased with the intent of transferring irrigation water for these lands to upstream storage or if storage is purchased outright.

POTENTIALLY FEASIBLE SITES STUDIED BY USDA

This section presents a brief discussion of 26 possible water resource development sites in Arizona that were studied by USDA (see Table 4-1). Included are 9 irrigation/recreation reservoir sites, 13 single purpose recreation reservoir sites, 1 site that discusses the possible utilization of intermittent storage in closed basins (Long, Whipple and Little Mormon Lake basins), and 3 sediment control sites (Aguirre Wash, Coyote Creek, and Youngs Canyon Tank). Several of these sites have previously been investigated by the Arizona Game and Fish Department.

POTENTIAL RECREATION/IRRIGATION RESERVOIRS

1. Benny Creek

This site is located in Apache County within the Apache-Sitgreaves National Forest about two miles southwest of Greer in the SW 1/4, Section 15, T. 7 N., R. 27 E.

Benny Creek is a main tributary to the Little Colorado River. It heads on a timbered ridge about one mile northwest of Sheep Crossing and flows generally northeast to its confluence with Hall Creek about three miles north of Greer. Elevations range from 9,600 feet in the upper watershed to 9,080 feet at the dam site. The drainage area at the site is 3.15 square miles, entirely within the National Forest. The watershed is in the Montane Conifer Forest Vegetation Community, consisting of timbered hills and ridges and mountain meadows.

The proposed sturcture is an earthfill dam located where Benny Creek leaves a large mountain meadow and enters a canyon. The dam would span the entrance to the canyon (see Photos 4-1 and 4-2), with a crest length of 300 feet, rising 42 feet above the stream bed. The structure would store 1,000 acre-feet, with a surface area of 110 acres and maximum depth of 32 feet.

Jointed basalt is exposed in both abutments. Seepage losses may be of sufficient magnitude to require treatment. The emergency spillway would be located through a ridge on the north abutment, requiring a 33 foot cut from top of ridge to spillway crest. The spillway crest would be in basalt which may require concrete lining or other treatment to insure a stable spillway. The estimated construction cost of the structure is $96,000. The site is on national forest land.

This site could be a single or multi-purpose recreation/irrigation reservoir. Storage may involve a water right conflict with downstream irrigation interests. A recreation lake at this site would be similar in quality to the adjacent Colter Reservoir or Lee Valley Reservoir. Any feasibility study conducted at this site should include a study of recreation demand because there are numerous other recreation lakes in close proximity to this site, including the Greer Lakes, Crescent Lake, Big Lake, Lee Valley, and Sunrise Lake.

2. Bigelow Crossing (State, Butler)

These sites are located in Apache County west of Eagar. There have been various proposals to construct a dam across the main stem of the Little Colorado River west of Eagar since about 1950. There are three different sites proposed: Bigelow Crossing, State, and Butler. These sites have also been referred to as Bigelow Crossing No.'s 1, 2, and 3. The farthest downstream is Bigelow Crossing No. 1, located in Section 12, T8N, R28E, approximately two miles west of Eagar. The middle site (State) is located in Section 16, T8N, R28E, approximately three miles upstream from the Bigelow Crossing Site. The upper site (Butler) is located in Section 17, T8N, R28E, approximately one mile upstream from the State site. Of these three sites, the lower (Bigelow Crossing) appears to be the most feasible and is the subject of discussion in this writing.

The Bigelow Crossing site is located in the northeast 1/4, southwest 1/4, of Section 12, across the main stem of the Little Colorado River. The proposed dam is immediately upstream from where State Highway 273 crosses the river (see Photo 4-3). The drainage area at the site is approximately 76 square miles. Elevations range from 11,403 feet in the upper watershed at the top of Mount Baldy to 7,120 at the site. Most of the watershed lies within the Apache-Sitgreaves National Forest. The dam site and reservoir area are on private land.

The proposed structre is an earthfill dam with a total length of about 450 feet, rising 38 feet above the river bed. The structure would store 1,600 acre-feet,

Photo 4-1: Benny Creek Site, looking northeast. The proposed dam would bridge the entrance to the canyon, center of photo.

Photo 4-2: Benny Creek Site, looking west (upstream). The proposed dam would bridge the canyon outlined by the basalt outcrops.

with a surface area of 88 acres. The embankment would require approximately 90,000 cubic yards of fill. The right abutment is on an alluvial terrace. The left abutment is on jointed basalt with a vertical slope. Seepage rates could be high through both sides of the canyon. The emergency spillway would be located on basalt through the left abutment. The estimated construction cost of the structure is $300,000.

Photo 4-3: Bigelow Crossing Site, looking upstream from Highway 273 bridge, across the proposed reservoir area.

Reconnaissance level studies of this site have been conducted on several occasions by the Arizona Game and Fish Department and the Soil Conservation Service. A topographic map of the site was completed in 1960, and the left, or north canyon wall, was diamond drilled in 1954.

This site could be a single-purpose or multi-purpose recreation/irrigation reservoir. Detailed studies have never been conducted because of objections to storage at this site by the downstream Lyman Water Company. The proposal usually lies dormant for several years, then is resurrected in wet years whenever there is sufficient runoff to cause flow through the spillway at Lyman Reservoir. One proposal to offset downstream objections would be to transfer a part of the storage from the upstream White Mountain Reservoir, which has high evaporation losses, downstream to the Bigelow Crossing site. A storage transfer of 1,600 acre-feet has been proposed by local interests, and this is the amount used by USDA to size the structure discussed in this report.

The site has potential for storage, although additional investigation is needed to compare the evaporation and seepage losses with White Mountain Reservoir. This site is in series with several upstream dams, the main one being River Reservoir at Greer. River Reservoir Dam is an old structure that does not meet present-day standards. It was suggested to USDA during the course of this study that River Reservoir be abandoned and the storage transferred downstream to the Bigelow

Crossing site. This is an option; however, the Bigelow Crossing Reservoir site is downstream of the diversion heading for Big Ditch, and irrigation waters would have to be pumped out of the reservoir in order to serve the irrgated lands presently supplied by Big Ditch. Also, the U.S. Forest Service has substantial investments in access and recreational facilities at River Reservoir. More facilities are planned. Abandonment of the reservoir would be detrimental to recreation, the summer homes at the lake, and the economy of the nearby Greer community.

The Biglow Crossing site has some characteristics of a Type 5 - Inland Open Fresh Water Wetland. Construction would change the site to a fresh water lake.

3. Davis Creek

This site is located in Apache County about six miles northeast of Nutrioso in the South 1/2, Section 13, T7N, R30E.

Davis Creek is a tributary to Nutrioso Creek. It heads on Escudilla Mountain and flows north and west joining Nutrioso Creek about one and a half miles upstream from Nelson Reservoir. Elevations range from 10,800 feet in the upper watershed at the top of Escudilla Mountain to 8,220 feet at the dam site. The drainage area at the site is 3.17 square miles, entirely within the Apache-Sitgreaves National Forest. The watershed is in the Montane Conifer Forest Vegetation Community. A portion of the watershed, on the north slope of Escudilla Mountain, is a revegetated burn.

The proposed structure is an earth fill dam located across a shallow canyon (see Photo 4-4) about one half mile downstream from Forest Road No. 1275. There are several alternative reservoir sizes possible at this site. The most efficient would be a small reservoir with the water depth equal to the height of the canyon walls (about 25 feet, storing 125 acre-feet), however, there is sufficient runoff to have a larger reservoir of about 500 acre-feet. The smaller reservoir is recommended. The dam would have a crest length of 550 feet, rising 35 feet above the stream bed. The structure would store 125 acre-feet, with a surface area of 7 acres and maximum depth of 25 feet.

Photo 4-4: Davis Creek Site, looking upstream (south) across the dam site toward Escudilla Mountain.

Andesitic basalt crops out on both abutments. The emergency spillway would be located in basalt on the right abutment. The estimated construction cost of the structure is $117,000. The dam site and reservoir are on national forest land.

Davis Creek is a possible site for reintroduction of threatened Arizona native trout (Salmo Apache), and the proposed site is a winter range for deer and elk. There are presently no other storage reservoirs on Davis Creek. The Creek is a tributary to Nutrioso Creek and supplies some water to Nelson Reservoir. In addition, there is a diversion located about one mile downstream from the Davis Creek site that is used to divert water through an earth ditch to Reagan Reservoir, a shallow lake that provides valuable wildlife habitat. Any storage at Davis Creek may involve a water right conflict with Nelson Reservoir, Reagan Reservoir, or irrigation interests at Springerville and St. Johns.

4. Escudilla

This site is located in Apache County about ten miles northeast of Alpine in the SW 1/4, NW 1/4, Section 26, T7N, R31E. It is on Morrison Creek approximately one half mile west of the Arizona-New Mexico line.

Morrison Creek heads on the east slope of Escudilla Mountain, joins with Mamie Creek approximately one mile downstream from the dam site and then flows northward, essentially parallel to the Arizona-New Mexico line. Elevations range from 10,180 feet in the upper watershed to 8,380 feet at the dam site. The drainage area at the dam site is 2.98 square miles, including 2.62 square miles in Arizona and 0.36 square miles in New Mexico. The watershed is in the Montane Conifer Forest Vegetation Community. The entire watershed is within the Apache-Sitgreaves National Forest.

The proposed structure is an earthfill dam to be located approximately 1/4 mile upstream from where Miller Scott Spring joins Morrison Creek. The site is where the creek leaves a mountain meadow and enters a small canyon (see Photo 4-5).

Photo 4-5: Escudilla Dam Site, looking north across the reservoir area. The proposed dam would bridge the entrance to the canyon, approximate center of photo.

The dam would span the entrance to this canyon, rising 80 feet above the stream bed. The structure would store 800 acre-feet, with a surface area of 40 acres and maximum depth of 70 feet. Two separate dam sections are required. The main dam would span the canyon with a length of approximately 400 feet. A saddle dike would be required on the northwest side of the reservoir to prevent flow over a ridge. This dike would have a maximum height of 10 feet with length of 700 feet. The emergency spillway would be located through a basalt knoll on the left abutment between the main dam and saddle dike.

This site has andesitic basalt outcrops on both abutments. Jointing of the rock in outcrops may be indicative of potential seepage problems. Shallow soils make borrow materials scarce, possibly requiring long haul distances.

The estimated construction cost of the structure is $650,000. The dam site and reservoir are on national forest land.

Morrison Creek flows into Mamie Creek, another candidate stream for reintroduction of Arizona native trout. Stocking of introduced trout species into the proposed reservoir might result in cross breeding with the native trout proposed for Mamie Creek.

This site was proposed in the 1950's as a recreation lake by the Arizona Game and Fish Department. The site was abandoned in 1959 because of water right conflicts with downstream irrigation interests. Downstream storage on Morrison Creek includes storage at Conservation Reservoir No. 1 (H-V), Conservation Reservoir No. 2, and several stock ponds. The creek is a tributary to Coyote Creek, which eventually joins with the Little Colorado River above Lyman Lake. The Escudilla site offers fair potential as a recreation lake if water rights and environmental conflicts could be resolved; however the site is not very efficient. [1/]

5. Sheep Springs

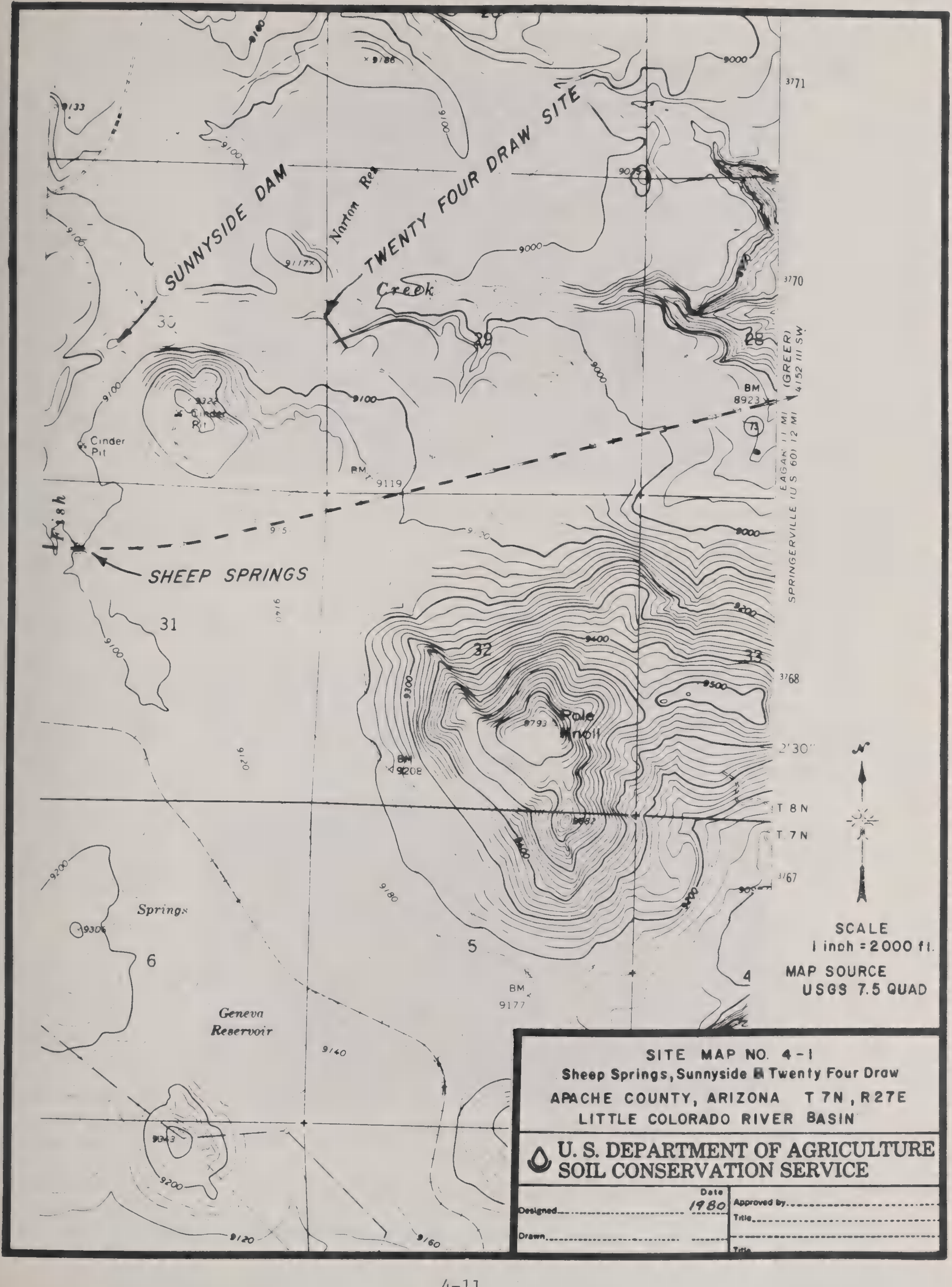
This site is located in Apache County in the Apache-Sitgreaves National Forest on Fish Creek approximately four miles northwest of Greer in the northwest 1/4, Section 31, T8N,R27E. It is 1 1/4 miles downstream from Geneva Reservoir and 1/2 mile upstream from Sunnyside Dam (see Sunnyside and Twenty Four Draw proposals and Site Map No. 4-1).

The embankment and spillway for this reservoir are already in place (see Photo 4-6). The embankment is a fill on Arizona State Highway 73. The fill was constructed with an impervious blanket on the upstream face and a spillway was constructed at the same time.

This site was first proposed as a recreation reservoir by the Arizona Game and Fish Department in the 1950's and efforts by the Department were instrumental in modifying the highway fill to act as a dam. Negotiation for water rights were unsuccessful. Their proposals included a lake with a capacity of 390 acre-feet and surface area of 40 acres at the Sheep Springs site, and the construction of an embankment at the upper end of the reservoir to provide a supplemental impoundment of about 145 acre-feet.

The total drainage area to this site is 2.91 square miles including 0.98 square miles controlled by Geneva Reservoir. There is sufficient runoff to fill the 390

1/ An "inefficient" site as used in this report is a judgemental term and is used to generally describe a site that has high construction cost or height of dam compared to the volume of storage or reservoir surface area provided by the reservoir.



SUNNYSIDE DAM
TWENTY FOUR DRAW SITE
SHEEP SPRINGS
Norton Res
Creek
Cinder Pit
Pole Knoll
Springs
Geneva Reservoir
SPRINGERVILLE (U S 60) 12 MI
EAGAR 11 MI
(GREER)
4152 III SW
T 8 N
T 7 N
2'30"
SCALE
1 inch = 2000 ft.
MAP SOURCE
USGS 7.5 QUAD
SITE MAP NO. 4-1
Sheep Springs, Sunnyside & Twenty Four Draw
APACHE COUNTY, ARIZONA T 7N, R27E
LITTLE COLORADO RIVER BASIN
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed
Date
1980
Drawn
Approved by
Title

Photo 4-6: Sheep Springs Site, looking north, showing highway embankment.

Photo 4-7: Sheep Springs Site, looking south from highway, showing proposed reservoir area.

acre-feet Sheep Springs site in most years. Outcrops of jointed basalt in the reservoir (see Photo 4-7) suggest a potential for high seepage losses. These outcrops could be blanketed with impervious fill material if excessive seepage losses occurred.

The only structural item necessary to convert this site into a water holding reservoir is a gate on the highway culvert (see Photo 4-6). This could be accomplished at an estimated cost of $2,000; an extremely low figure for the creation of a 390 acre-feet recreation lake. The embankment is on Arizona Department of Transportation right-of-way. The reservoir area is on national forest land.

This site has some of the characteristics of a Type 5 - Inland Open Fresh Water Wetland. It would be changed to a fresh water lake.

6. Sizer Knoll

This site is located in Apache County, 2 1/2 miles east of Greer in the N 1/2, northwest 1/4, Section 17, T7N, R28E. It is 3/4 mile southeast of Sizer Knoll and one mile northeast of Hay Lake. The site is on an unnamed tributary to the South Fork of the Little Colorado River.

The watercourse heads on a forested ridge and flows north through a mountain meadow before beginning a plunge off a steep rim to join with South Fork. The proposed site is at the head of a steep canyon that leads over the rim. Elevations range from 9,220 feet at the top of the watershed to 9,030 feet at dam site. The watershed is in the Montane Conifer Forest Vegetation Community consisting of high mountain meadow and timbered hills and ridges. The drainage area at the dam site is 1.04 square miles.

The proposed structure is an earthfill dam extending 450 feet across the canyon entrance (see Photos 4-8 and 4-9). The structure would rise 52 feet above the canyon floor, with a storage of 300 acre-feet, surface area of 44 acres at a maximum depth of 42 feet. The spillway would be located in basalt on the right abutment. The estimated construction cost of the structure is $200,000. The dam and reservoir are on national forest land.

This site could be a single or multi-purpose recreation/irrigation reservoir. Storage may involve a water rights conflict with downstream irrigation interests. The only road to this site is an old unimproved logging road that would require upgrading to provide normal public access.

7. South Fork Spring

This site is located in Apache County on the South Fork of the Little Colorado River, about three miles southeast of Greer in the N 1/2, Section 20, T7N, R28E. It is five miles due north of Crescent Lake; approximately one mile downstream of the Head of South Fork Spring and 1/2 mile downstream from where Forest Road 1409 crosses South Fork Canyon.

The total drainage area at the site is 5.75 square miles, including 1.09 square miles controlled by Hog Wallow Lake, 0.43 square miles controlled by Pool Corral Lake, and 4.23 square miles uncontrolled.

Hog Wallow and Pool Corral Lakes are intermittent storage lakes where low dikes have been constructed to increase storage in natural depressions. Both lakes are irrigation storage reservoirs for the Lyman Water Company (see Inventory of Existing Reservoirs and Lakes).

Photo 4-8: Sizer Knoll Site, looking east along approximate centerline of proposed dam. The dam would span the canyon in forefront of photo.

Photo 4-9: Sizer Knoll Site, looking southwest from dam site showing reservoir area.

The drainage area to the South Fork Spring site consists of high mountain meadows and conifer forest. Elevations range from 9,520 feet at Wahl Knoll to 9,030 feet at the dam site.

The proposed structure is an earthfill dam across South Fork Canyon (see Photos 4-10 and 4-11). The dam would have a crest length of 600 feet and height of 52 feet; storing 2,000 acre-feet with a surface area of 60 acres and at a maximum depth of 42 feet.

Basalt and tuffaceous materials outcrop on the canyon walls and some seepage would probably occur. The spillway could probably be placed on basalt around the left abutment, however, concrete lining of the spillway may be required. The estimated construction cost of the structure is $300,000. This does not include costs for relocation of Forest Road 1409 which presently goes through the proposed reservoir area. The dam site and reservoir are on national forest land.

This site has good potential as a single purpose or multi-purpose recreation/irrigation reservoir. To reduce existing water losses, it might be preferable to abandon Hog Wallow Lake and Pool Corral Lake as irrigation storage reservoirs and transfer their storage to the South Fork Spring site, although draining these lakes would be detrimental to waterfowl and other wildlife.

Storage at this site may involve a water right conflict with downstream irrigation interests. If Hog Wallow Lake and Pool Corral Lake are maintained in their present usage, provisions would have to be made to allow water from these lakes to pass through the South Fork Spring Site to satisfy downstream rights.

8. Sunnyside Dam

This site is located in Apache County on Fish Creek about four miles northwest of Greer in the SW 1/4, Section 30, T8N, R27E. It is 1/2 mile downstream from the Sheep Springs site (see Sheep Springs and Twenty Four Draw proposals and Site Map No. 1). There is an existing dam at this site (see Photo 4-12). The outlet pipe is a hollowed out log which has rotted out and the dam no longer holds water (see Inventory of Existing Reservoirs and Lakes).

The drainage area to this site is 6.72 square miles, including 0.98 square miles controlled by Geneva Reservoir and 5.74 square miles uncontrolled. Construction at the upstream Sheep Springs site would reduce the uncontrolled drainage area to 3.81 square miles. The dam site is at elevation 9,060.

The proposal is to remove the existing dam and construct a new embankment. The construction necessary would be very similar to that used in the past to repair two other old irrigation dams; Little Joe Rencher and Canyon Dams. The new structure would be an earthfill dam with a crest length of 400 feet, height of about 30 feet; storing 400 acre-feet at a maximum depth of 20 feet with a surface area of 38 acres. The emergency spillway would be moved from the right abutment and placed in the left abutment through a vesicular basalt outcrop. Concrete lining of the spillway should not be required. The right abutment of the dam and a portion of the pool area are on a cinder knoll capped by a shallow soil layer, which could cause excessive seepage. The estimated construction cost of the structure is $50,000. The dam and reservoir are on national forest land.

Photo 4-10: South Fork Spring Site, looking north from Forest Road 1409 down South Fork Canyon. The proposed dam would span the canyon approximately where the basalt rock is exposed on the left canyon wall.

Photo 4-11: South Fork Spring Site, looking southeast, showing proposed reservoir area.

Photo 4-12: Sunnyside Dam Site, looking downstream on Fish Creek, showing reservoir area and existing dam.

Although the site has potential, it may involve a water rights problem with downstream irrigation interests. The Sunnyside Dam would be within the reservoir area of the proposed Twenty Four Draw Dam located downstream (see description below), therefore, both dams could not be constructed.

This site has some of the characteristics of a Type 5-Inland Fresh Water Wetland. Construction would change the site to a fresh water lake.

9. Twenty Four Draw

This site is located in Apache County on Fish Creek (Twenty Four Draw) about four miles northwest of Greer approximately on the section line between Sections 29 and 30, T8N, R27E (see Site Map No. 1). It is located 1/2 mile upstream from where the Norton Reservoir drainage joins with Fish Creek; approximately 3/4 mile downstream from the existing Sunnyside Dam; and approximately 1 1/2 mile downstream from where Arizona State Highway 73 crosses Fish Creek (Sheep Springs Dam Site).

Fish Creek is a mountain stream that heads at Geneva Reservoir and flows north and east through mountain meadows before plunging steeply over a rim to join with the Little Colorado River approximately four miles north of Greer. Water is diverted out of Fish Creek at a point just underneath the rim and carried to the north via an earth ditch to irrigate lands in the vicinity of Antelope Mountain. This ditch supplies water to Ellis Wiltbank Reservoir and Wiltbank Reservoirs No. 1, 2, 3 and 4 (see Inventory of Existing Lakes and Reservoirs). The proposed Twenty Four Draw site is located approximately one mile upstream from where Fish Creek goes over the rim and approximately two miles upstream from the diversion for the irrigation ditch.

The Fish Creek drainage consists of high mountain meadow and conifer forests. Elevations in the upper watershed include 9,793 feet at Pole Knoll, 9,593 feet at Big Cinega Mountain, and 9,913 feet at an unnamed peak immediately south of Swinborne Spring. The elevation at the dam site is 9,020 feet.

There are three reservoirs upstream from this site; Geneva Reservoir, Sheep Springs and Sunnyside. Geneva Reservoir is a shallow irrigation storage reservoir. Sheep Springs Dam and Sunnyside Dam do not retain water (see Inventory of Existing Lakes and Reservoirs and the Site Reports for Sheep Springs and Sunnyside Sites elsewhere in this section of the Appendix).

The total drainage area at the Twenty Four Draw site is 8.07 square miles including 0.98 square miles controlled by Geneva Reservoir and 7.09 square miles uncontrolled, of which 1.93 square miles are above the Sheep Springs site. The conversion of the Sheep Springs site to a water holding reservoir would reduce the net uncontrolled drainage area to 5.16 square miles.

The proposed structure would be an earthfill dam across Fish Creek (see Photos 4-13 and 4-14). The dam would have a crest length of 650 feet and height of 62 feet. It would store 1,600 acre-feet, with a surface area of 140 acres at a maximum depth of 50 feet.

Rock, in the form of jointed vesicular basalt, outcrops in both abutments. There may be a possibility of cinder beds within or under the basalt. The spillway could be placed on stable rock through either abutment. More detailed examination is necessary to determine the expected amount of seepage at this site.

The estimated construction cost of the structure is $380,000. The dam and reservoir are on national forest land.

This site has good potential as a single purpose or multi-purpose recreation/irrigation reservoir. The reservoir surface area is only 140 acres, however, it is long and narrow creating in excess of 2 1/2 miles of shoreline. The reservoir would inundate the existing Sunnyside Dam, requiring the removal of that structure. It might be preferable to abandon Geneva Lake as an irrigation reservoir and transfer the storage to the Twenty Four Draw site, although this would be detrimental to waterfowl. If not, provisions would have to be made to allow water from Geneva Reservoir to pass through the Twenty Four Draw site in order to satisfy downstream water rights.

POTENTIAL RECREATION LAKES

10. Barbershop Canyon

This site is located in Coconino County approximately 23 miles west of Heber in the SE 1/4, Section 9 and SW 1/4 Section 10, T12N, R11E. It is six miles west of Knoll Lake.

Barbershop Canyon is a tributary to East Clear Creek. The drainage area at the site is 2.19 square miles. Elevations range from 7,830 feet in the upper watershed along the Mogollon Rim to 7,370 feet at the site. The watershed cover consists of pine mixed conifer. The site is in a deep pine covered canyon.

The proposed structure would be an earthfill dam with a crest length of 300 feet, height of 80 feet, maximum storage of 900 acre-feet at a depth of 68 feet and surface area of 35 acres.

Photo 4-13: Twenty Four Draw Site, looking south across canyon, showing approximate location of dam.

Photo 4-14: Twenty Four Draw Site, looking east, showing reservoir area.

The site is underlain by Coconino sandstone. The spillway would be located through sandstone on the left abutment and would require concrete lining. The estimated construction cost of the structure is $400,000, not including costs for access roads or recreational facilities. The dam and reservoir are on national forest land. This is an inefficient site. Construction of access roads would be difficult and expensive.

11. Beaver Canyon

This site was proposed as a recreation lake by the Arizona Game and Fish Department in the 1960's. It is located thirty miles west of Heber in the SW 1/4, Section 19, T12N, R13E, and the SE 1/4, Section 24, T12N, R12E. It is 1 1/2 miles west of Bear Canyon Lake.

The site is located within the Apache-Sitgreaves National Forest on Beaver Canyon, a tributary to Chevelon Creek. The drainage area at the site is 3.52 square miles. Elevations range from 7,890 feet in the upper watershed on the Mogollon Rim to 7,410 feet at the dam site. The watershed cover consists of pine mixed conifer. The site is in a steep pine covered canyon (see Photo 4-15).

The proposed structure would be an earthfill dam with a crest length of 420 feet and height of 75 feet. It would store 1,500 acre-feet, with a surface area of 60 acres and maximum depth of 62 feet.

Coconino sandstone is present in the abutments. The sandstone is jointed and may be conducive to high seepage rates. The spillway would be located through sandstone in the left abutment and would require concrete lining to protect it from erosion. The estimated construction cost of the structure is $600,000. This does not include any costs for access roads or recreational facilities. The dam and reservoir are on national forest land. This is an inefficient site.

Photo 4-15: Beaver Canyon Site, looking west from a powerline right-of-way across reservoir area.

12. Buck Springs

This site is located in Coconino County within the Coconino National Forest approximately 33 miles west of Heber in the southeast 1/4, Section 31, T13N, R12E. It is 3 miles northwest of Knoll Lake.

Buck Springs Canyon is a tributary to East Clear Creek. The drainage area at the site is 2.63 square miles. Elevations range from 7,800 feet in the upper watershed to 7,210 feet at the site. The watershed cover consists of pine mixed conifer. The site is in a deep pine covered canyon.

The proposed structure would be an earthfill dam with a crest length of 800 feet, height of 80 feet, storing 800 acre-feet at a maximum depth of 68 feet and surface area of 40 acres.

The site is in the Coconino sandstone formation. The spillway would be located through sandstone on the right abutment and would require concrete lining. The estimated construction cost of the structure is $700,000, not including costs for access roads and recreational facilities. The dam and reservoir are on national forest land. This is an inefficient site.

13. Clark Springs

This site (see Photo 4-16) is located in Coconino County within the Coconino National Forest nine miles southeast of Flagstaff in the northeast 1/4, southwest 1/4, Section 32, T20N, R8E. It is on an unnamed tributary to Walnut Creek. The tributary goes into Upper Lake Mary approximately 2 1/2 miles upstream from the dam.

Photo 4-16: Clark Spring Site, looking northeast (downstream) across the reservoir area. The dam would abut into the limestone ridge, left of photo.

The drainage area at the site is 5.63 square miles. Elevations range from 7,712 feet at Coulter Hill in the upper watershed to 6,890 feet at the site. The watershed cover consists of mountain meadows and pine covered slopes.

The proposed structure would be an earthfill dam with a crest length of 800 feet and height of 52 feet. It would store 1,500 acre-feet, with a surface area of 85 acres and maximum depth of 40 feet.

Kaibab Limestone outcrops on both abutments. The emergency spillway would cut through a limestone ridge on the left abutment. There is a potential for high seepage through both abutments.

The estimated construction cost of the dam is $390,000. The dam and reservoir area are on national forest land.

This site has potential as a single purpose recreation reservoir; however, there are numerous other recreational lakes, including Lower Lake Mary, Upper Lake Mary, and Ashurst Lake within a few miles of the site.

14. Dane Canyon

This site is located in Coconino County within the Coconino National Forest approximately 32 miles west of Heber in the NE 1/4, Section 26, T13N, R11E. It is 5 miles northwest of Knoll Lake.

Dane Canyon is a tributary to East Clear Creek. The drainage area at the site is 6.60 square miles. Elevations range from 7,930 feet in the upper watershed along the Mogollon Rim to 7,040 feet at the site. The watershed cover consists of pine mixed conifer. The site is in a deep pine covered canyon approximately 1/4 mile downstream from the junction with Moonshine Draw.

The proposed structure would be an earthfill dam with a crest length of 480 feet, height of 155 feet, storing 2,700 acre-feet at a maximum depth of 140 feet and a surface area of 60 acres.

Kaibab limestone crops out on the ridge tops. It is underlain by Coconino sandstone. The spillway would be located through a natural saddle on the right abutment and would require concrete lining. The estimated construction cost of the structure is $2,500,000, not including any costs for access roads or recreational facilities. The dam and reservoir are on national forest land. This is an inefficient site. Construction of access roads would be difficult and expensive.

15. Gentry Canyon

This site is located in Coconino County within the Apache-Sitgreaves National Forest, approximately 31 miles southwest of Heber in the NE 1/4, Section 11, T12N, R12E. It is two miles northeast of Knoll Lake.

Gentry Canyon is a tributary to Chevelon Creek. The drainage area at the site is 3.59 square miles. Elevations range from 7,812 feet in the upper watershed to 7,350 feet at the site. The watershed cover consists of pine mixed conifer. The site is in a steep pine covered canyon approximately 1/2 mile downstream from Double Cabin Spring (see Photo 4-17). Forest Road No. 1140A crosses Gentry Canyon approximately 1/4 mile upstream from the dam site.

Photo 4-17: Gentry Canyon Site, looking south (upstream), showing reservoir area.

The proposed structure would be an earthfill dam with a crest length of 600 feet and height of 80 feet. It would store 2,000 acre-feet, with a surface area of 72 acres at a maximum depth of 65 feet.

The site is underlain by the Coconino sandstone. Some jointing is evident in outcrops. Although some seepage will occur, this site has potential for a recreation reservoir. The spillway would be located through sandstone in the left abutment and would require concrete lining to protect it from erosion. The estimated construction cost of the structure is $830,000. The dam and reservoir are on national forest land. Construction would cause the loss of elk and other wildlife habitat, including riparian areas.

16. Jacks Canyon

This site is located in Coconino County about 28 miles southwest of Winslow on Jacks Canyon in the southeast 1/4, Section 29, T16N, R12E. It is at the junction of Chavez Draw and Jacks Canyon about 200 yards downstream from Forest Road No. 469. The proposed dam would span the entrance to a steep walled canyon (see Photos 4-18 and 4-19).

The drainage area at the site is 110.9 square miles. Elevations range from 7,320 feet in the upper watershed on Blue Ridge to 6,130 feet at the site. Jacks Canyon is a major tributary to the Little Colorado River, joining the River near Clear Creek southeast of Winslow.

The proposed structure would be an earth-and-rockfill dam with a crest length of 380 feet, height of 130 feet, storing 8,800 acre-feet at a maximum depth of 115

Photo 4-18: Jacks Canyon Site, looking northeast. The dam would plug the notch in the canyon wall, center of photo.

Photo 4-19: Jacks Canyon Site, closeup of the notch shown in Photo 4-18. View is looking downstream. The dam would be across this notch.

feet and surface area of 200 acres. Impounded waters would extend approximately 2 miles up Jacks Canyon and 1.7 miles up Chavez Draw. The reservoir would inundate approximately a 2 mile length of the unimproved Forest Road No. 469. The spillway would be located through Kaibab limestone on the right abutment and would require concrete lining. The estimated construction cost of the structure is $1,500,000, not including costs for access roads, recreation facilities, or the relocation of Forest Road No. 469. The dam and most of the reservoir area is on national forest land. Approximately 40 acres of the reservoir in Section 5, T15N, R12E, are on private land.

This is an efficient site and has potential as a single purpose recreation reservoir. The Arizona Game and Fish Department investigated a fish and wildlife reservoir at the site; however, it was rejected in 1972 because of poor geology. USDA investigated this site in 1979. The valley upstream from the site parallels the axis of a breached anticline. The valley may also be located along a fault line. The attitude of rocks in the left abutment suggests faulting. The site is primarily in the Kaibab limestone, however, Coconino sandstone crops out in the abutment and along the valley walls. Open joints are common on the surface but may be closed at relatively shallow depths.

The geologic suitability of this site is questionable but detailed investigation could prove it to be suitable. This site has several advantages that may warrant further study. The drainage area is 110.9 square miles, the site is very efficient in regard to dam volume versus storage, and Jacks Canyon offers perhaps one of the few storage sites in the Basin where upstream storage may not involve major conflicts over water rights. In contrast, rerouting of Forest Road 469 could be expensive and the site may conflict with the Chavez Pass archeological site or other archeological resources in the area.

17. Leonard Canyon

This site is located in Coconino County within the Coconino National Forest approximately 33 miles west of Heber in the NE 1/4, Section 8, T12N, R12E. It is on West Leonard Canyon just downstream of the junction with Sandstone Canyon. West Leonard Canyon is a tributary to East Clear Creek. The site is 1 1/2 miles northeast of Knoll Lake.

The drainage area at the site is 7.33 square miles. Elevations range from 7,920 in the upper watershed along the Mogollon Rim to 7,200 feet at the site. The watershed cover consists of pine mixed conifer. The site is in a deep pine covered canyon (see Photo 4-20).

The proposed structure would be an earthfill dam with a crest length of 500 feet and height of 120 feet. It would store 2,600 acre-feet, with a surface area of 65 acres at a maximum depth of 100 feet.

The site is located in the Coconino sandstone which may be subject to high seepage rates. The emergency spillway would be located through sandstone on the right abutment and would require concrete lining. The estimated construction cost of the structure is $1,500,000. This does not include any costs for access roads or recreational facilities. The dam and reservoir are on national forest land. This is an inefficient site, and it might disrupt elk migration to and from the winter range. Also, access by road would be difficult, expensive, and would mar the natural beauty of the canyon.

Photo 4-20: Leonard Canyon Site, looking east from Hospital Ridge, showing junction of West Leonard and Sandstone Canyons.

18. Nutrioso (Red Rock, Flying Box Irrigation, Beaver Bear)

The Nutrioso sites are located in Apache County on Nutrioso Creek about four miles east of Springerville. Four sites have been proposed, all in close proximity to each other on a six mile reach of the creek between Correjo Crossing (downstream of Nelson Reservoir) downstream to where U.S. Highway 60 crosses Nutrioso Creek. The Arizona Game and Fish Department refers to all four sites as Nutrioso and their proposals call for a fish and wildlife reservoir either in Section 5, T8N, R30E; Section 25, T9N, R29E; Section 31, T9N, R30E; or Section 36, T9N, R29E. These sites have also been referred to as Red Rock, Flying Box Irrigation, and Beaver Bear M&I, although it is not entirely clear as to which name applies to which site.

The Section 36 site has received the most attention and investigation. This is an existing 60 feet high fill where U.S. Highway 60 crosses Nutrioso Creek (see Photo 4-21). In 1962 the Arizona Game and Fish Department proposed that the highway fill be modified to act as a dam to create a recreation reservoir. The Department proposed to purchase 123 acres of irrigated land at Springerville downstream of the site, and apply the water right to maintaining evaporation losses in Nelson Reservoir plus filling of the Nutrioso site. This proposal was dropped in 1963 because of objections from the Lyman Water Company.

USDA reviewed the four Nutrioso sites. They all offer excellent physical potential for the construction of a reservoir of about 1,500 acre-feet capacity. The Section 36 site still appears to be the best; however, the total drainage area to this site is 163.7 square miles, including 86.8 square miles controlled by Nelson Reservoir. The construction of a chute spillway at this site, which must pass underneath Highway 60, would be very expensive considering the large drainage area. Further investigation of all four sites is strongly recommended if the conflict over water rights can be resolved.

Photo 4-21: Nutrioso (Section 36) Site. View shows upstream face of Highway 60 fill and three 120 inch diameter culverts.

19. Sawmill Springs

This site (see Photo 4-22) is located in the Coconino National Forest thirty miles southeast of Flagstaff in the southeast 1/4, Section 20, T17N, R10E. It is on Sawmill Wash, a tributary to Canyon Diablo.

The drainage area at the site is 3.60 square miles. Elevations range from 8,200 feet in the upper watershed on the north slope of Hutch Mountain to 7,260 feet at the site. The watershed cover is primarily mixed conifer.

The proposed structure would be an earthfill dam with a crest length of 600 feet and height of 65 feet. It would store 1,000 acre-feet, with a surface area of 120 acres at a maximum depth of 55 feet.

The site is underlain by basalt and does not appear to have serious limitations. The spillway would be placed in basalt on the right abutment.

The estimated construction cost of the dam is $320,000. The dam and reservoir area are on national forest land.

This site has potential as a single purpose recreation reservoir. Approximately five miles downstream from this site is a diversion on Sawmill Canyon that diverts water to Luther Hart Tank on Canyon Diablo and then to Soldier Lake via Soldier Annex Canal. The impact on downstream water supplies resulting from a dam at the Sawmill Springs site has not been determined; however, the impact should be minor considering the small drainage area affected. Conflicts with downstream water users should be expected, as the site is on the same watershed as the past proposed Crisis Lake, which met with heavy opposition, and was never constructed.

This site has some of the characteristics of a Type 5-Inland Open Fresh Water Wetland. The site would be change to a fresh water lake.

Photo 4-22: Sawmill Springs Site, looking east (downstream).

20. Scotts Reservoir

This is an existing irrigation reservoir located in Navajo County about one mile northeast of Lakeside (see Inventory of Existing Reservoirs and Lakes). It has been proposed that this lake be enlarged. Storage capacity would be increased to maintain a minimum pool for recreation. USDA viewed this site in 1979. It appears that an increase in storage could be accomplished by raising the dam, blocking the existing spillway, and constructing a new spillway through basalt on the right (north) abutment. This possibility was not studied in depth. The dam is in need of repair. The most immediate need from a recreational standpoint would be to improve access, construct recreational facilities, and negotiate with the Show Low Irrigation Company about maintaining a minumum pool.

21. Turkey Canyon

This site is located in Coconino County about two miles northwest of Bear Canyon Lake in Section 13, T12N, R12E. It was proposed as a fish and wildlife lake by the Arizona Game and Fish Department in the early 1960's. Detailed planning was not done because it is an inefficient site in comparison with the other Rim Lakes. It has potential; however, USDA agrees with earlier opinions that the site is inefficient. USDA did not prepare any preliminary design or cost estimates for this site. The drainage area is 3.36 square miles.

22. Yeager Canyon

This site is located in Coconino County about four miles northwest of Knoll Lake in Section 24, T13N, R11E. It is on Yeager Canyon, a tributary to East Clear Creek.

The drainage area at this site is 4.62 square miles. Elevations range from 7,905 feet in the upper watershed along the Mogollon Rim to 7,110 feet at the site. The site is in a deep pine covered canyon.

The proposed structure would be an earthfill dam with a crest length of 500 feet and height of 97 feet. It would store 1,500 acre-feet, with a surface area of 50 acres at a maximum depth of water of 82 feet.

The site is underlain by the Coconino sandstone. It is an inefficient site. The abutments are steep, presenting problems tying-in the dam and also for the spillway. The estimated construction cost of the structure is $1,090,000. This does not include any costs for access roads, which would be expensive, or recreational facilities. The dam and reservoir are on national forest land.

POTENTIAL DEVELOPMENT OF INTERMITTENT STORAGE IN CLOSED BASINS

23. Long, Whipple, and Little Mormon Lakes

These three lakes are in Navajo County within the Apache-Sitgreaves National Forest approximately two miles northeast of Show Low. They are in natural closed basins. Little Mormon, located in Sections 1 and 12, T10N, R22E, is the easternmost lake. It is separated from Whipple Lake by a narrow ridge approximately 40 feet high. Whipple Lake, the middle lake, and Long Lake, the westernmost lake, are both located within the same closed basin. They are separated at low water levels, joining together when the water reaches a depth of approximately 6 feet (see Photo 4-23). The Long Lake/Whipple Lake basin is located in Sections 9, 10, 11, 14, and 15, T10N, R22E. The three lakes are located approximately half-way between two tributaries to Silver Creek; Rocky Arroyo on the east and Show Low Creek on the west. Rocky Arroyo joins Silver Creek above White Mountain Reservoir; Show Low Creek joins Silver Creek near Shumway.

Little Mormon Lake has permanent storage. The natural drainage area of 7.09 square miles has been increased to 33.7 square miles by diverting water from Rocky Arroyo. In 1980, the downstream Showlow-Silver Creek Water Conservation and Power District constructed facilities at Little Mormon Lake in order to increase storage and use impounded waters for irrigation. These facilities included dikes around the lake to increase storage, a buried pipeline on the east side to drain the lake eastward into the Silver Creek drainage via Rocky Arroyo, and a ungated spillway on the west side to spill flood flows westward over the ridge into the Long Lake/Whipple Lake closed basin.

The Long Lake/Whipple Lake basin is approximately 2 1/2 miles long and 3/4 mile wide. The basin retains water only during wet years. There is no outflow. Runoff is retained until lost by seepage or evaporation. The bottom of the basin is approximately 40 feet lower than the surrounding terrain. The low point in the terrain is a ridge on the west end of Whipple Lake; the top of the ridge being about 20 feet higher than the bottom of the lake. The natural drainage area to the basin is 11.0 square miles. The total drainage area available to the basin is 44.7 square miles considering the additional 33.7 square miles that could be diverted from Little Mormon Lake and Rocky Arroyo. The Long Lake/Whipple Lake basin is capable of

Photo 4-23: Long Lake and Whipple Lake. View is looking west from Little Mormon Lake across the Long/Whipple Lake basin. Whipple Lake is in the foreground, Long Lake is in the background.

trapping large volumes of water during wet years. Most of the runoff comes from spring snowmelt. In the spring of 1979, it is estimated that Long Lake and Whipple Lake captured 5,000 acre-feet and 600 acre-feet respectively.

The proposal for Long, Whipple, and Little Mormon Lakes is to connect the three lakes together and be able to drain all three westward into Show Low Creek. Three facilities are needed: (1) a gated, buried pipeline to connect Little Mormon and Whipple Lakes, (2) an open channel cut between Whipple Lake and Long Lake, and (3) drainage facilities at the west end of Long Lake to drain water from all three lakes into Show Low Creek (see Site Map No. 4-2). The gated pipeline between Little Mormon and Whipple would require a 35 foot cut through the ridge between the lakes. The pipe would be 400 feet long, with a vertical gate and shaft to be located near the midpoint of the ridge. Water could only be drained westward; elevation differences would not allow flow eastward from Whipple Lake to Little Mormon.

The open channel cut between Whipple and Long Lake would be approximately 1,200 feet long with a 6 foot maximum depth of cut.

The drainage facilites at the west end of Long Lake could be an open channel, buried pipeline, or combination of both. The most feasible appears to be a buried pipeline which would begin at the west end of Long Lake (see Photo 4-24), follow the lowest natural terrain westward underneath the ridge separating the Long Lake basin from Show Low Creek, and outlet into Show Low Creek at a point 1/2 mile north of the City sewage disposal ponds and one mile upstream from Fools Hollow Lake. The pipeline would be 5,150 feet long, requiring a maximum depth of cut of 25 feet. The size of this pipeline would be dependent upon a desired time for lake drainage; a 30 inch diameter concrete pipe would release 13 to 22 CFS and drain 3,000 acre-feet, 4,000 acre-feet, and 5,000 acre-feet in 92 days, 116 days, and 154 days respectively.

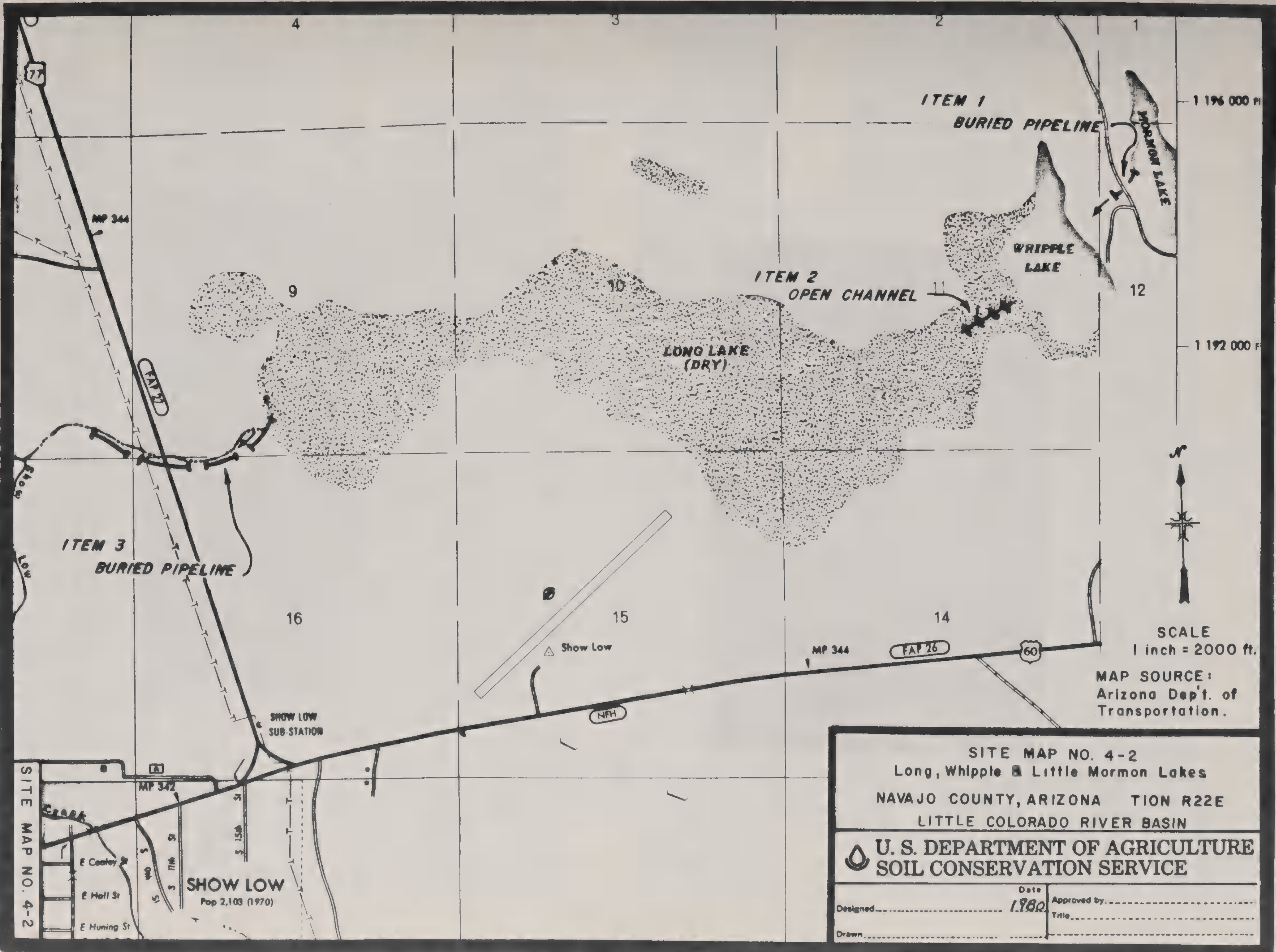

ITEM 1
BURIED PIPELINE
MORMON LAKE
WHIPPLE LAKE
ITEM 2
OPEN CHANNEL
LONG LAKE
(DRY)
ITEM 3
BURIED PIPELINE
1 196 000 FT
1 192 000 FT
1
2
3
4
9
10
11
12
14
15
16
77
MP 344
FAP 77
Show Low
MP 344
FAP 26
60
NFH
SHOW LOW
SUB-STATION
MP 342
E Cooley St
E Hall St
E Huning St
SHOW LOW
Pop 2,103 (1970)
SCALE
1 inch = 2000 ft.
MAP SOURCE:
Arizona Dep't. of
Transportation.
SITE MAP NO. 4-2
Long, Whipple & Little Mormon Lakes
NAVAJO COUNTY, ARIZONA TION R22E
LITTLE COLORADO RIVER BASIN
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed
Date
1980
Approved by
Title
Drawn
SITE MAP NO. 4-2

Photo 4-24: Long Lake, looking east from the west end of the lake at a point near Whipple Well. The proposed pipeline would begin near the extreme right of photo.

The estimated construction cost of the project is $206,000, including $20,000 for the pipe between Little Mormon and Whipple Lakes, $1,100 for the open channel cut between Whipple and Long Lakes, and $184,900 for a buried 30 inch diameter concrete pipe to drain Long Lake to Show Low Creek. Little Mormon Lake, Whipple Lake, the eastern 2/3 of Long Lake, and the last 2,000 feet of the Long Lake pipeline, including the outlet, are on national forest land. The western 1/3 of Long Lake, the pipeline inlet, and the first 3,150 feet of the pipeline are on private land. The pipeline would cross State Highway 77 approximately one mile north of the junction with U.S. Highway 60.

This project would allow system management of the Little Mormon/Whipple/Long Lake basins. Little Mormon could be drained eastward into the Silver Creek drainage or westward into Whipple Lake. Long Lake and Whipple Lake could be drained westward into Show Low Creek.

Whipple Lake and Long Lake are Type 1-Seasonally Flooded Basins or Flats Wetlands. Little Mormon Lake is an inland fresh water lake. There are long range plans for waterfowl nesting areas to be built in the Long Lake Basin. Draining the lake could complicate these plans, and environmental opposition should be expected.

POTENTIAL SEDIMENT CONTROL STRUCTURES

This section presents data on three sites that offer potential as sediment control reservoirs. The reader should not infer that these are the only structural erosion and sediment control sites in the Basin.

24. Aguirre Wash

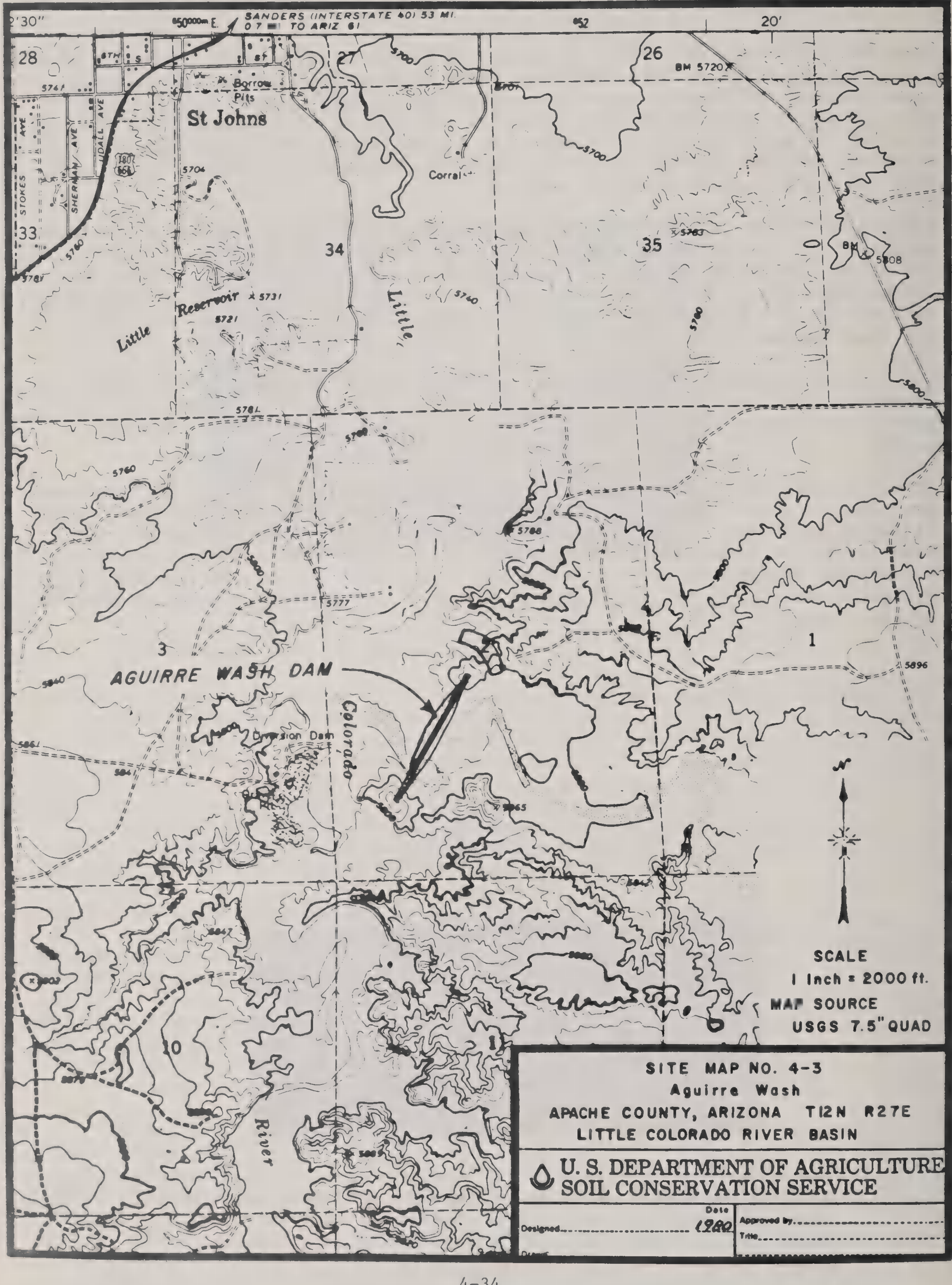
This site is located in Apache County about 2 1/2 miles south of St. Johns, Arizona in the S 1/2 Section 2, T12N, R28E (see Photo 4-25 and Site Map No.4-3). The proposed dam would be located across an unnamed wash, locally called Aguirre Wash, which is a main tributary to the Little Colorado River. The dam site is at the mouth of the wash, on the east side of the Little Colorado River and opposite the diversion dam that diverts water from the Little Colorado River into Little Reservoir for the St. Johns Irrigation Company.

Aguirre Wash is an intermittent flow watercourse that heads in New Mexico and flows northwest to its confluence with the Little Colorado River. The watershed is long and narrow, averaging approximately 3 miles in width and 26 miles in length. Elevations range from 7,900 in the upper watershed to 5,280 at the mouth. The drainage area at the site is 73.5 square miles, of which 71.5 square miles are in Arizona and 2.0 square miles are in New Mexico.

Outcropping geologic materials within the watershed include the Triassic Chinle formation, Tertiary sandstone, shale and conglomerate, Quaternary sand, silt and gravel, Quaternary basalt, and possibly Shinarump conglomerate of the Triassic period.

This wash, with an average annual sediment yield of about 115,000 ton (59 acre-feet) per year, is a major source of damaging sediment to the Little Colorado River downstream of Lyman Dam. Sediment deposition in the channel of the Little Colorado River at St. Johns has restricted the channel, requiring reconstruction of the U.S. Highway 666 bridge, contributes to the high water table and drainage problem in the irrigated lands north of St. Johns, and restricts the flood water carrying capacity of the channel.

Photo 4-25: Aguirre Wash Site, looking southwest across the wash. The proposed dam would be between the ridge shown at lower right of photo and the juniper covered ridge across the wash.



SANDERS (INTERSTATE 40) 53 MI.
St Johns
Borrow Pits
Corral
Little Reservoir
Little
Colorado
River
AGUIRRE WASH DAM
Diversion Dam
SCALE
1 Inch = 2000 ft.
MAP SOURCE
USGS 7.5" QUAD
SITE MAP NO. 4-3
Aguirre Wash
APACHE COUNTY, ARIZONA T12N R27E
LITTLE COLORADO RIVER BASIN
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed
Date
1980
Approved by
Title

The proposed structure would be an earthfill sediment detention dam at the mouth of Aquirre Wash. The dam would be 50 feet in height to the emergency spillway crest and 62.5 feet high to top of dam.

The structure would store 2,650 acre-feet with a surface area of 180 acres at the emergency spillway crest. The storage is equivalent to a 50 year sediment storage or to 0.68 inches of sediment from the total watershed area.

The emergency spillway would be a concrete lined chute spillway located through a natural saddle on the right abutment. This spillway, with a bottom width of 250 feet, would convey the freeboard hydrograph for an SCS Class (high hazard) storm event.

This proposal does not include storage for floodwater. The sediment storage pool (2,650 acre-feet) would provide some storage for such purposes as: recreation, fish and wildlife, stockwater and floodwater; however, the available capacity would diminish over time due to sediment accumulations. The storage could be increased by raising the dam, however, the costs would appreciately increase because the saddle where the emergency spillway would be located could not be used.

Geology maps indicate that the damsite probably is on an outcrop of the Chinle formation which consists of interbedded sandstone and shale. On the basis of this data, the emergency spillway would require lining to prevent excessive erosion. The Shinarump conglomerate may crop out near the site. If the spillway could be founded in this material, concrete lining might not be required. Bedrock may be present within a depth of 15 feet or less in the foundation area.

The estimated construction cost of the structure is $910,000. The right abutment of the dam and a part of the spillway are on private land. Most of the site is on State Trust land.

The 50 year sediment storage provided (2,650 acre-feet) would reduce the present sediment damage at St. Johns and provide some storage for such purposes as flood prevention, recreation, fish and wildlife and stockwater. The structure would improve the water quality of the Little Colorado River by removing sediment and would recharge the groundwater.

It is not anticipated that construction would involve any endangered or threatened plants or animals. There are no known archeological or historical resources at the site. However, the possibility of impacts on any of these resources cannot be discounted.

25. Coyote Creek

This site is located in Apache County about ten miles north of Springerville in the SE 1/4, Section 9 and the NE 1/4, Section 16, T10N, R29E. The proposed dam is located across Coyote Creek, about five stream miles upstream form where it joins the Little Colorado River. The confluence is about three miles upstream of Lyman Lake.

Coyote Creek is an intermittent flow watercourse. It heads on Escudilla Mountain and runs in a northerly direction to its confluence with the Little Colorado. Elevations range from 10,800 feet in the upper watershed to 6,475 feet at the site. The cover consists of pine mixed conifer in the upper watershed and juniper-pinyon and grasslands in the lower elevations. The drainage area to the site is 197.1 square miles, including 148.8 square miles in Arizona and 48.3 square miles in New

Mexico. The total Coyote Creek drainage area to the junction with the Little Colorado River is 221.8 square miles. The proposed structure would control 89% of this area, and 25% of the total drainage area to Lyman Lake.

The proposed structure would be an earthfill floodwater and sediment detention dam consisting of two sections; a main dam across the canyon entrance and a saddle dike across a swale in the northwest part of the reservoir area. The main dam would be 101 feet high with a crest length of 400 feet. The saddle dike would have a maximum height of 26 feet with a crest length of 2,600 feet. The structure would store 22,610 acre-feet, including 12,610 acre-feet for the 100-year sediment volume and 6,000 acre-feet of temporary floodwater detention storage. The maximum depth of the sediment pool would be 76 feet with a surface area of 500 acres. The emergency spillway would be placed through a basalt ridge on the right abutment between the main dam and saddle dike. The spillway crest would be in erosion resistant basalt and lining should not be requuired.

This site is underlain by basalt of Quaternary Age. The rock is fractured. Some treatment may be required to control seepage; however, this should not be a major problem. The foundation appears to be non-yielding. Adequate materials for construction of the dam are available nearby.

The emergency spillway has been designed for the SCS Class b (medium hazard) freeboard hydrograph. A failure at this site would possibly endanger the downstream Lyman Dam. Detailed hydrologic studies may indicate the need to increase the spillway capacity at Lyman Dam or else use a higher hazard classification at the Coyote Wash site.

This structure could be designed for either a wet or dry sediment pool. A wet sediment pool would provide storage for such purposes as recreation, fish and wildlife or stockwater; however, this storage would detract from the water supply for Lyman Lake.

This is an extremely efficient reservoir site, requiring a relatively small dam for a large amount of storage. The estimated construction cost of the structure is $930,000. The entire site is on private land. Until recently it was State Trust land, but it was purchased by a utility company as a possible well field to provide cooling water for a coal fired power plant now under construction. The amount of possible conflict between using this site as a reservoir versus a well field has not been determined as of this writing.

26. Youngs Canyon Tank

This site is located in Coconino County within the Coconino National Forest twelve miles west of Flagstaff in the NE 1/4, Section 35, T21N, R9E. It is three miles due south of Winona. It is located on Youngs Canyon, a major tributary to Canyon Diablo.

There is a breached dam at this site (see Inventory of Existing Lakes and Reservoirs and Photo 4-26). The dam failed in December 1978. Trash marks on the remains of the dam indicate that the probable cause of failure was overtopping because of insufficient spillway capacity. The spillway is located on the left abutment in dense layered limestone of the Kaibab formation.

The drainage area at the site is 15.3 square miles. The site is at elevation 6,280. The dam is approximately 30 feet high.

Photo 4-26: Youngs Canyon Tank, looking south along the upstream face of the dam. The breached section can be seen within the fence, left center of photo.

It is proposed that this dam be repaired. This would require replacing the breached section and lowering of the emergency spillway. The estimated construction cost of this repair is $20,000. The dam and reservoir are on national forest lands.

This site has little value as a recreation reservoir; however, there are several reasons why repairs are recommended. This is an efficient site and it could be repaired at minimal expense. Bedrock exposed in the spillway appears to be capable of withstanding substantial flows without excessive erosion. It would provide a limited source of water for livestock and wildlife. A complete failure of the dam is inevitable unless repairs are made. This will result in gully erosion through the trapped sediments upstream from the dam, land voiding, and flushing of sediments downstream. Sites like Youngs Canyon Tank that offer the opportunity to prevent erosion at minimal expense are rare.

UNFEASIBLE RESERVOIR SITES STUDIED BY USDA

A listing of fourteen unfeasible sites is shown in Table 4-2. Some of these are new proposals first considered by USDA during the course of this River Basin Study. The Dipping Vat, Hoxworth Springs, Indian Hill, and Turkey Track sites have been proposed for several years. A further discussion of these four sites is given below:

Dipping Vat

This site is located in Navajo County on Silver Creek approximately two miles downstream from Daggs Dam in Section 4, T11N, R22E. This site has been proposed

TABLE 4-1

POTENTIALLY FEASIBLE SURFACE WATER DEVELOPMENT SITES STUDIED BY USDA
ARIZONA PORTION, LITTLE COLORADO RIVER BASIN
JANUARY 1980

MAP NO.	NAME	LOCATION	COUNTY	STREAM	TRIBUTARY TO	DRAINAGE AREA (SQ. MI.)	TYPE OF STRUCTURE PROPOSED	WATER DEPTH (FT)	HT. OF DAM (FT)	SURFACE AREA (AC)	CAPACITY (AF)	LAND STATUS	CONSTRUCTION COSTS 1/ TOTAL ($)	COST PER ACRE OF SURFACE AREA ($ PER AC.)	COST PER AF STORAGE ($ PER AF)	REMARKS
RECREATION OR IRRIGATION RESERVOIRS																
1	Benny Creek	S15,T7N,R27E	Apache	Benny Creek	Hall Creek	3.15	Earthfill	32	42	110	1,000	USFS	96,000	873	96	5/
2	Bigelow Crossing	S12,T8N,R28E	Apache	Little Colorado	--	76.00	Earthfill	25	38	88	1,600	Private	300,000	3,409	188	5/
3	Davis Creek	S13,T7N,R30E	Apache	Davis Creek	Nutrioso Creek	3.17	Earthfill	25	35	7	125	USFS	117,000	16,714	936	Inefficient site 5/
4	Escudilla	S26,T7N,R31E	Apache	Morrison Creek	Coyote Creek	2.98	Earthfill	70	80	40	800	USFS	650,000	16,250	813	Inefficient site 5/
5	Sheep Springs	S31,T8N,R27E	Apache	Fish Creek	Little Colorado	2.91	Highway Fill	20 est.	--	43	390	USFS	2,000	47	5	5/
6	Sizer Knoll	S17,T7N,R28E	Apache		South Fork	1.04	Earthfill	42	52	44	300	USFS	200,000	7,445	667	Inefficient site 5/
7	South Fork Spring	S20,T7N,R28E	Apache	South Fork	Little Colorado	5.75	Earthfill	42	52	60	2,000	USFS	300,000	5,000	150	5/
8	Sunnyside	S30,T8N,R27E	Apache	Fish Creek	Little Colorado	6.72	Earthfill	20	30	38	400	USFS	50,000	1,316	125	Replacement of existing dam 5/
9	Twenty Four Draw	S29-T8N,R27E	Apache	Fish Creek	Little Colorado	8.07	Earthfill	50	62	140	1,600	USFS	380,000	2,714	238	Construction would inundate Sunnyside site 5/
RECREATION RESERVOIRS																
10	Barbershop Canyon	S9,10,T12N,R11E	Coconino	Barbershop Canyon	East Clear Creek	2.19	Earthfill	68	80	35	900	USFS	400,000	11,429	444	Inefficient site 4/
11	Beaver Canyon	S19,24,T12N,R13E	Coconino	Beaver Canyon	Chevelon Creek	3.52	Earthfill	62	75	60	1,500	USFS	600,000	10,000	400	Inefficient site 4/
12	Buck Springs	S31,T13N,R12E	Coconino	Buck Springs Canyon	East Clear Creek	2.63	Earthfill	68	80	40	800	USFS	700,000	17,500	875	Inefficient site 4/
13	Clark Springs	S32,T20N,R8E	Coconino		Walnut Creek	5.63	Earthfill	40	52	85	1,500	USFS	390,000	4,588	260	4/
14	Dane Canyon	S26,T13N,R11E	Coconino	Dane Canyon	East Clear Creek	6.60	Earthfill	140	155	60	2,700	USFS	2,500,000	41,667	926	Inefficient site 4/
15	Gentry Canyon	S11,T12N,R12E	Coconino	Gentry Canyon	Chevelon Creek	3.59	Earthfill	65	80	72	2,000	USFS	830,000	11,528	415	Inefficient site 4/
16	Jacks Canyon	S29,T16N,R12E	Coconino	Jacks Canyon	Little Colorado		Earth and Rock	115	130	200	8,800	USFS, Private	1,500,000	7,500	170	Questionable geology. Needs detailed investigation 3/

TABLE 4-1 (Continued)

POTENTIALLY FEASIBLE SURFACE WATER DEVELOPMENT SITES STUDIED BY USDA
ARIZONA PORTION, LITTLE COLORADO RIVER BASIN
JANUARY 1980

MAP NO.	NAME	LOCATION	COUNTY	STREAM	TRIBUTARY TO	DRAINAGE AREA (SQ. MI.)	TYPE OF STRUCTURE PROPOSED	WATER DEPTH (FT)	HT. OF DAM (FT)	SURFACE AREA (AC)	CAPACITY (AF)	LAND STATUS	CONSTRUCTION COSTS 1/ TOTAL ($)	COST PER ACRE OF SURFACE AREA ($ PER AC.)	COST PER AF STORAGE ($ PER AF)	REMARKS	
17	Leonard Canyon	S8,T12N,R12E	Coconino	Leonard Canyon	East Clear Creek	7.33	Earthfill	100	120	65	2,600	USFS	1,500,000	23,077	577	Inefficient site	4/
18	Nutrioso (4 sites)	S36,T9N,R29E S25,T9N,R29E S31,T9N,R29E S5,T8N,R30E	Apache	Nutrioso Creek	Little Colorado	163.7	Highway Fill Earthfill Earthfill Earthfill	48	60	60	1,200	State, Private					4/
19	Sawmill Springs	S20,T17N,R10E	Coconino	Sawmill Wash	Canyon Diablo	3.60	Earthfill	55	65	120	1,000	USFS	320,000	2,667	320		4/
20	Scotts Reservoir	S13,T9N,R22E	Navajo	Porter Creek	Show Low Creek	34.5	Earthfill	37		75	1,450	Private				Needs improved access & rec. facilities. Lake could be enlarged 3/	
21	Turkey Canyon	S13,T12N,R12E	Coconino	Turkey Canyon	Chevelon Creek	3.36	Earthfill					USFS				Inefficient site	4/
22	Yeager Canyon	S24,T13N,R11E	Coconino	Yeager Canyon	East Clear Creek	4.62	Earthfill	82	97	50	1,500	USFS	1,090,000	21,800	727	Inefficient site	4/
DEVELOPMENT OF WETLAND PLAYAS																	
23	Long, Whipple, & Little Mormon Lakes	T10N,R22E	Navajo	Closed Basins	Show Low Creek & Rocky Arroyo	44.7	Drainage Facilities Channel & Pipeline	--	--	--	5,600	USFS, Private	206,000	--	37	Intermittent storage	6/
SEDIMENT CONTORL STRUCTURES																	
24	Aguirre Wash	S2,T12N,R28E	Apache	Aguire Wash	Little Colorado	73.5	Earthfill	50	62.5	180	2,650	Private, State	910,000	5,056	343		
25	Coyote Creek	S9,16,T10N,R29E	Apache	Coyote Wash	Little Colorado	197.1	Earthfill	76 2/	101	500 2/	12,610 2/	Private	930,000	1,860	74	Floodwater storage = 10,000 AF	
26	Youngs Canyon Tank	S35,T21N,R9E	Coconino	Youngs Canyon	Canyon Diablo	15.3	Earthfill		30			USFS	20,000			Rehabilitation of breached dam 3/	

1/ 1979 Costs
2/ These values are only for the 100-year sediment pool
3/ The Arizona Game and Fish Department states that they would be able to support this project. (Reference No. 1)
4/ The Arizona Game and Fish Department states that these sites should remain open for consideration pending future recreational use pattern development, environmental impacts, demands for other natural resources in the area and construction costs. (Reference No. 1)
5/ The Arizona Game and Fish Department states that they cannot actively support this project. (Reference No. 1)
6/ This project opposed by the Arizona Game and Fish Department. (Reference No. 1)

TABLE 4-2

UNFEASIBLE RESERVOIR SITES STUDIED BY USDA
ARIZONA PORTION, LITTLE COLORADO RIVER BASIN
JANUARY 1980

MAP NO.	NAME	LOCATION	COUNTY	STREAM	TRIBUTARY TO	DRAINAGE AREA (SQ. MILES)	PROPOSED PURPOSE	REASONS FOR UNFEASIBILITY
27	Baca Cemetary	S30,T11N,R16E	Navajo	Black Canyon	Chevelon Creek	2.99	Recreation	Poor geology. Leakage in Kaibab limestone.
28	Benny Creek (Lower)	S36,T8N,R27E	Apache	Benny Creek	Hall Creek		Recreation or Irrigation	Poor geology. Leakage in fractured basalt.
29	Bluff	S9,T11N,R16E	Navajo	Black Canyon	Chevelon Creek	10.74	Recreation	Pool geology. Leakage in Kaibab limestone.
30	Chavez Canyon	S29,T16N,R12E	Coconino	Chavez Draw	Jacks Canyon	15.53	Recreation	Poor geology. Site is in fault strike valley
31	Cottonwood Upper	S4,T10N,R19E	Navajo	Cottonwood Wash	Silver Creek		Recreation	Poor geology. Jointed sandstone and faulting.
32	Dipping Vat	S4T11N,R22E	Navajo	Silver Creek	Little Colorado		Recreation or Irrigation	Poor geology. Leakage in basalt.
33	Ellsworth Point	S31,T11N,R19E	Navajo	West Fork	Cottonwood Wash	4.77	Recreation	Poor geology.
34	Gillespie Flat	S25,T9N,R25E	Apache	Vernon Creek	Mineral Creek		Recreation	Poor geology. Leakage in basalt.
35	Grapevine Canyon	T17N,R10E	Coconino	Grapevine Canyon	Canyon Diablo		Recreation	Questionable geology. Archeological ruins.
36	Hall Creek	S25,T8N,R27E	Apache	Hall Creek	Little Colorado		Recreation or Irrigation	Poor geology. Leakage in fractured basalt.
37	Hoxworth Springs	S8,T19N,R8E	Coconino		Walnut Creek	1.20	Recreation	Small D.A. Questionable need.
38	Indian Hill	S10,T12N,R28E	Apache	Little Colorado		820.00	Recreation Irrigation	Questionable need.
39	Turkey	S21,T11N,R16E	Navajo	Turkey Canyon	Black Canyon	2.09	Recreation	Poor geology. Small D.A.
40	Turkey Track	S14,T9N,R22E	Navajo	Show Low Creek	Silver Creek	55.0 est.	Recreation	Questionable need.

as an irrigation reservoir or recreation reservoir for over 20 years. It has been investigated on several occasions by the Soil Conservation Service and Arizona Game and Fish Department and has been rejected because of the potential for excessive leakage through basalt canyon walls.

Hoxworth Springs

This site is located in Coconino County about 10 miles southeast of Flagstaff in the NE 1/4, Section 8, T19N, R8E. It has been proposed as a possible fish and wildlife reservoir since the 1960's. USDA investigated this site in 1979 and it has some potential; however, it is felt that the adjacent Clark Springs site previously described in this report is superior to the Hoxworth Springs site. The drainage area to the Hoxworth Springs site is only 1.2 square miles.

Indian Hill (Salado Reservoir)

This proposed reservoir is located in Apache County on the main stem of the Little Colorado River about six miles downstream from Lyman Dam and three miles above the City of St. Johns. There are three sites that have been proposed. A report prepared by USDA Bureau of Agricultural Economics, on the Lyman Reservoir Project in 1939 (12) showed a proposed Salado Dam for irrigation in Section 16, T12N,R28E. The report also mentions a Big Salado Dam in Section 17,T12N,R28E, which failed in 1904. In 1955, the St. Johns Irrigation Company proposed to construct a large irrigation storage reservoir in the NW 1/4, Section 10, T12N, R28E. The Soil Conservation Service completed a topographic survey of the site, conducted soil tests, and did some preliminary geological investigations. Further investigation was suspended because of a conflict over water rights. In the 1960's the Arizona Game and Fish Department had preliminary proposals for a fish and wildlife reservoir at another site in Section 15, T12N, R28E.

USDA reviewed these sites in 1979 but did not conduct any more investigations. The value of an irrigation reservoir at either site is highly questionable. The sites are downstream from Salado Springs. The water from these springs have a TDS in excess of 2,200 PPM, making it very poor quality water for irrigation. The need for a recreation reservoir is also questionable because Lyman Lake is only a few miles upstream.

Turkey Track

This site is located in Navajo County on Show Low Creek about one mile north of Lakeside in Section 14, T9N, R22E. It was proposed as a fish and wildlife lake by the Arizona Game and Fish Department in the 1960's. There are several lakes, including Show Low Lake, Scotts Reservoir, Rainbow Lake and others, within a 1 1/2 mile radius of this site. Another reservoir in the area is probably not needed.

SUMMARY AND CONCLUSIONS REGARDING USDA SITE INVESTIGATIONS

The sites studied by USDA for this River Basin Study that offer a potential for development of surface water within the Basin are summarized in Table 4-1. USDA does not advocate development at all of these sites. Each is offered only as a possibility. Indeed, it may be that resources would most profitably be devoted to protecting and improving existing facilities rather than creating new ones.

There is very little opportunity to construct quality reservoirs in the Basin. Water is scarce and over-subscribed. Most of the good sites have been developed.

Competition for scarce natural resources generates conflicts between users, particularly when development has an unfavorable impact upon wildlife habitat or other aspects of the natural environment. (The position of the Arizona Game and Fish Department, which is probably representative of many environmental concerns, in regard to the proposals in this report are shown in the footnotes for Table 4-1).

The least expensive site for a new irrigation/recreation reservoir in Apache County is the Sheep Springs site,although the surface area (43 acres) is smaller than desired for a public recreation lake. In fact, the Arizona Game and Fish Department recommends a minimum surface area of 500 acres for any future lakes. The best recreation reservoir site in Coconino County is probably Sawmill Springs. The Mogollon Rim lakes, (Barbershop Canyon, Beaver Canyon, Buck Springs, Dane Canyon, Gentry Canyon, Leonard Canyon, Turkey Canyon, and Yeager Canyon) are very inefficient sites requiring a large expense for minimal surface area. In addition, the construction of access roads to many of these sites would be difficult and expensive. Construction would have an adverse impact on wildlife and natural beauty. The only attractiveness that these sites offer is that they are located in a high runoff zone; the physical feasibility of construction in this area has already been demonstrated by the success of adjacent lakes such as Knoll Lake and Bear Canyon Lake; and the proposed sites are near the Phoenix Metro area. On the negative side, the existing rim lakes are under-utilized at present. Resources should be spent on improving access to the existing rim lakes, improving camping facilities and possible enlargement of the existing rim lakes to capture spillway spills that occur from spring runoff.

It is physically possible to regulate the storage in the Long, Whipple, Little Mormon Lake closed basins, although such endeavors would hardly be popular to all interests. Opposition to development is certainly to be expected.

Rehabilitation of the breached Youngs Canyon Tank is strongly recommended. Structures such as this that have a non-erosive spillway are very rare and the opportunity to repair this structure and prevent gully erosion should not be lost. The other two sediment control proposals, Aguirre Wash Dam and Coyote Creek Dam, would provide sediment control for downstream areas but an overall watershed treatment program, combining both structural and land treatment measures, would be the proper long range approach.

Although several sites studied by USDA offer the potential for additional irrigation storage, the need for any more storage at the sites investigated is subject to question. Resources should be spent on improving existing distribution systems and improved irrigation water management rather than construction of any new irrigation reservoirs.

Many existing recreation lakes appear to be under-utilized. Resources should perhaps be spent in the following areas rather than for new construction:

- More emphasis of urban lakes close to population centers. The attractiveness of remote sites will continue to diminish with increasing energy costs.

- Improve existing facilities, including improved access, waterweed control, and boating and camping facilities.

- Inventory and publicize fishing opportunities. There are many lakes in the Basin that offer quality fishing that are unknown to the general

public. Slade Lake, for example, was a quality fishery in the late 1960's following stocking by the Arizona Game and Fish Department, but few people other than local residents were aware of this. There are numerous stock ponds in Coconino County that offer good fishing, but again few people are aware of the opportunities available.

Conflicts over water rights have prevented the development of many reservoir sites, particularly in the White Mountains on the headwaters to the Little Colorado River. Recent construction activities at two large power plants near St. Johns and Springerville has caused a large population increase in these communities and irrigated lands are being subdivided, but there is no indication that irrigation water diversions have been decreased. This situation is not unique to the Little Colorado River Basin. There are few irrigated areas in the West that have the legal and institutional flexibility to adjust historical water use to meet changing conditions. Some of the water historically applied to the lands in the areas mentioned above or perhaps other areas in the Basin may eventually become available for other uses, perhaps even for upstream storage. Agencies with an interest in possible development may desire to continue their efforts toward upstream storage developments, past reversals notwithstanding. USDA has a national objective to prevent unwise development on farmlands. It may be preferable to have irrigated land purchased by public entities, such as the Game and Fish Department, with the intent of transferring water rights to upstream storage, rather than subdividing the land. The land and water would then be available for other public uses and for future generations if needed.

OTHER SURFACE WATER DEVELOPMENT PROPOSALS AND INVESTIGATIONS

This section presents brief discussions of various surface water development proposals at 35 sites within the Little Colorado River Basin. Included are eight multi-purpose reservoirs in Arizona and one in New Mexico investigated by the U.S. Bureau of Reclamation; three flood control sites considered by the Corps of Engineer as part of their studies to provide flood protection for Holbrook, Arizona; one flood control and recreation reservoir currently under investigation by the Soil Conservation Service under Public Law 566; seven reservoir proposals under consideration by the Little Colorado River Plateau Resource Conservation and Development Area (five recreation reservoirs, one irrigation reservoir, and one irrigation/recreation reservoir); three projects that would develop surface water supplies for M&I use for the City of Flagstaff; and twelve sites designated as miscellaneous. Several of these represent old proposals that are considered unfeasible. The sole intent of this discussion is to summarize the status of these proposals for future reference.

U.S. BUREAU OF RECLAMATION

The U.S. Bureau of Reclamation has studied several multipurpose reservoir sites in the Basin within the last 40 years. A brief summary of these projects is presented below. All but the Yellowhouse Project are in the Arizona portion of the Basin.

Black River-Springerville-St. Johns Project (M&I Storage Dam)

This project is located in southern Apache County. The proposal involved a transbasin diversion of water from the Salt River watershed into the Little Colorado River watershed to provide supplemental municipal and industrial and irrigation water supplies. Four dams were proposed: Crosby Crossing Dam on East Fork of Black River (Salt River drainage); Thompson Ranch Dam on West Fork of Black River;

Apache Dam on Snake Creek (Salt River drainage), and M&I Storage Dam on the Little Colorado River. The only proposed dam in the Little Colorado River Basin is the M&I Storage Dam, which would be located west of Eagar about at the Bigelow Crossing site. In 1968, the U.S. Bureau of Reclamation recognized that reformulation of the project was needed and that a feasible project, excluding irrigation, might be formulated.

Mogollon-Mesa Project (Wilkins Dam and Upper Lake Mary Dam).

This project is located in southern Coconino County. It was called the Flagstaff-Williams Project in early studies. The proposal includes a 228 foot high thin arch concrete dam, with a capacity of 45,000 acre-feet, on Clear Creek in Sections 31 and 32, T15N, R13E and replacement of the existing Upper Lake Mary Dam with a larger structure. Water for municipal and industrial purposes would be diverted from Clear Creek via pumping plants and pipeline to Flagstaff. The project was found to be engineeringly and environmentally feasible and economically justified in 1976(8); however, the City of Flagstaff has been unwilling to make the longterm funding commitment required.

Winslow-Holbrook Project (Wildcat Dam)

This project is located in southern Navajo County. The proposal included a 230 foot high dam, with a capacity of 49,000 acre-feet, on Chevelon Creek in Section 1, T14N, R15E. Water for municipal and industrial purposes would be diverted from the proposed reservior via a pumping plant and pipelines to Winslow and Holbrook. The plan was abandoned because of unfavorable geologic conditions in the proposed reservoir (8).

Gallup Project (Houck Dam)

The Houck Dam site is located on the Navajo Indian Reservation in Apache County on Black Creek, a tributary to the Puerco River, in Section 2, T24N, R30E. This site was first named Black Creek Dam and proposed as an irrigation reservoir to irrigate lands near Chambers and Sanders. In 1966, the name was changed to Houck Dam and the purpose changed to a multi-purpose reservoir with storage for recreation, fish and wildlife, and municipal water for Gallup, New Mexico. This project is no longer considered feasible.

Snowflake Project (Shumway Dam)

This project is located in southern Navajo County. The proposal included Shumway Dam and other improvements to provide supplemental irrigation water supplies, recreation and fish and wildlife facilities, and minor flood control. The Shumway Dam site is on Silver Creek about one mile south of Shumway in Section 31, T12N, R22E. This site has been intensively studied since about 1940. Early proposals also called for a tunnel from Lone Pine Reservoir on Show Low Creek to divert water into the Silver Creek drainage above Shumway Dam. This alternative was later deleted. The latest proposal called for a 152 foot high dam with a reservoir capacity of 40,000 acre feet at the Shumway site. In 1968, irrigation was dropped as a purpose, but a feasible project involving flood control, fish and wildlife, and recreation might be formulated.

Yellowhouse Project (Yellowhouse Dam and Black Rock Dam)

This project is located in Valencia County, New Mexico. The proposal includes the proposed Yellowhouse Dam and rehabilitation of the existing Black Rock Dam. The

Yellowhouse site is located on the Zuni River in Section 11, T10N, R18W, about 8 miles east of Zuni. The proposed structure, for flood control, sediment control, and irrigation, would be a 118 foot high earthfill dam with a reservoir capacity of 44,400 acre-feet and a maximum capacity of 141,400 acre-feet. The rehabilitation plan for Black Rock Dam consists of reconstructing the spillway and outlet works, placing riprap on the upstream face of the dam, and additional dike work. The purpose is to provide flood control, restore irrigation storage capacity, and provide capacity for future sediment. A feasibility report and environmental impact statement for the project is being prepared.

Other BR Sites (Forks Dam, Tucker Flat Reservoir and Walnut Creek Canyon)

The Forks Dam site is on the main stem of the Little Colorado River, just below the mouth of Silver Creek, and above the town of Woodruff. The proposed location is in Section 29, T16N, R22E. The Bureau of Reclamation did a reconnaissance level study at this site in 1963 contemplating storage for irrigation use at Holbrook and Joseph City. The plan was abandoned in favor of development of irrigation water from wells by local irrigation interests.

The Tucker Flat Reservoir site is located in Navajo County about nine miles north of Winslow in Section 23, T20N, R15E. In 1963 the U.S. Bureau of Reclamation proposed an 18,000 acre-foot irrigation reservoir at this site. Water would be obtained by diversion from Clear Creek. This proposal was abandoned in favor of development for M&I at the proposed Wildcat and Wilkins Reservoir sites.

The Walnut Creek Canyon site is located on Walnut Creek about 5 miles southeast of Flagstaff. At the request of local interest at Flagstaff, the BR investigated this site as a alternative to the proposed enlargement of Upper Lake Mary (see Mogollon Mesa Project). The site was rejected because of poor waterholding capability in faulted limestone (8).

U.S. CORPS OF ENGINEERS

In 1980, the Corps of Engineers investigated three dams and retention reservoirs as alternative plans to provide flood protection for the city of Holbrook, Arizona.

Adamana, Holbrook, and Woodruff Dam Sites

The Adamana site is on the Puerco River near Adamana and about 20 miles above the river's mouth. The Holbrook site is just below the confluence of the Puerco and Little Colorado Rivers. The Woodruff site is on the Little Colorado River below the mouth of Silver Creek. The Woodruff site is probably at or near the U. S. Bureau of Reclamation Forks Dam previously mentioned in this report. All three of these dams were found to be economically unfeasible and were abandoned in favor of a levee system at Holbrook (10).

USDA's PUBLIC LAW 566

The only project in the Basin currently being planned under the Watershed Protection and Flood Prevention Act, Public Law 566, is the Cottonwood Wash project.

Cottonwood Wash Project

This project is located in southern Navajo County. Project features include Cottonwood Wash Dam and Reservoir located on Cottonwood Wash, a tributary to Silver Creek

about one mile west of Snowflake in Section 22, T13N, R21E. The proposed structure is an earthfill dam for flood control and recreation. The completion of the plans have been delayed pending a firm commitment of local funds for the project.

LITTLE COLORADO RIVER PLATEAU RC&D PROPOSALS

This section briefly discusses the status of seven measures currently under consider--ation in the Little Colorado River Plateau Resource Conservation and Development Area that involve storage of surface water within the Basin.

Ganado Lake

This is an existing irrigation and recreation reservoir located on the Navajo Indian Reservation, Apache County, in Section 24, T27N, R26E (see Inventory of Existing Reservoirs and Lakes). In 1972, the Little Colorado River Plateau Resource Conservation and Development Area prepared a preliminary report proposing improvements for the dam, an increase in storage, recreation facilities, and other items. The measure is currently inactive, but still under consideration.

Hidden Lake

This is an existing lake located on the Navajo Indian Reservation in Apache County about eight miles southwest of Window Rock in Section 9, T25N, R30E. The main dam has been breached; however a small pool remains. The Navajo Tribe proposes relocation or reconstruction to provide greater storage for recreation and fish and wildlife. Engineering studies are pending.

Hopi Waterbased Recreation

This site is located in Navajo County about nine miles south of Second Mesa in Section 7, T26N, R17E. The proposal is to construct an off-channel irrigation/ recreation reservoir to collect low flows from the adjacent Polacca Wash. This would require a large, expensive diversion structure across Polacca Wash to divert water to the proposed reservoir. Polocca Wash at the proposed point of diversion is a 30 foot deep canyon. Detailed engineering studies are needed at this site.

Joseph City Irrigation Reservoir

This site is located in Navajo County about two miles east of Joseph City in Section 25, T18N, R19E. This proposal involves the construction of an off-channel irrigation reservoir. The water supply would be from the Little Colorado River via an existing diversion and irrigation canal. The proposed reservoir would act as a sediment trap and storage regulating reservoir with gravity inflow and pumped outflow. The Soil Conservation Service has prepared preliminary plans for this project. Construction has been deferred due to local financing difficulties.

Trout Lake

This is an existing lake on the Navajo Indian Reservation about eight miles northwest of Fort Defiance in Section 28, T2N, R6W (Navajo Baseline). The dam no longer holds water because of damaged outlet facilities. The Navajo Tribe proposes the repair and improvement of this dam to create a recreation reservoir. Engineering studies are pending.

Woodruff Lake

This site is located in Navajo County about 1/2 mile northeast of Woodruff in Section 16, T16N, R22E. The Woodruff Irrigation District has proposed an irrigation/recreation reservoir at the site to be formed by constructing low dikes to increase storage in a low area. The water supply would come from Silver Creek via an abandoned irrigation ditch which begins at Woodruff Reservoir about four miles south of Woodruff and follows the canyon walls of the Little Colorado River through a complex system of siphons, hanging flumes, cable-suspended pipelines, and open ditch. The Woodruff Lake proposal is contingent upon repair of this old irrigation system. The measure is currently being studied by Navajo County Parks Department.

Woodruff Reservoir

This is an existing dam and reservoir located at the mouth of Silver Creek in Section 32, T16N, R22E (see Inventory of Existing Reservoirs and Lakes). The reservoir is formed by a concrete masonry dam whose original purpose was to divert water for irrigation through the irrigation system described above in the Woodruff Lake proposal. The reservoir is almost completely silted in. The Navajo County Parks Department has proposed improvements at this site, including silt removal and recreational facilities.

FLAGSTAFF M&I WATER SUPPLY

The City of Flagstaff has a severe water shortage problem. There have been several studies (2, 3) made on methods to obtain additional water for the City. Most of these proposed the development of well fields. There are five projects that involve the development of surface water: (1) the Mogollon Mesa Project, (2) the Inner Basin Surface Water Pipeline, (3) the Tremaine-Soldiers Annex Project, (4) the Anderson Mesa Project and (5) Mormon Lake. The Mogollon Mesa Project is being studied by the U.S.Bureau of Reclamation. It has been discussed previously in this report. The Inner Basin Surface Water Pipeline proposes to divert about 100 acre-feet per year from Freidlein Canyon on the west slopes of the San Francisco Peaks to Flagstaff. The other three projects are discussed below. All three are opposed by the Arizona Game and Fish Department because of their potentially detrimental effect to the wildlife habitat in and around the Anderson Mesa area (1).

Tremaine-Soldier Annex Project

This project would take an estimated 4,000 acre-feet per year from Tremaine, Soldier Annex, Soldier, and Long Lakes (see map entitled Existing Reservoir and Lakes and Table 4-3) for M&I use at Flagstaff. Water from these lakes would be piped through a 28-mile pipeline to the southeast side of Mormon Lake thence northward to Lower Lake Mary. The 1972 costs of this project were \$4.19 million without a standby well field and \$6.03 million with a well field (2).

Anderson Mesa Project

Anderson Mesa is a large plateau about 20 miles southeast of Flagstaff. It is about eight miles wide extending eastward from Mormon Lake and about eight miles in length. There are 13 permanent or intermittent storage lakes on this plateau. The Anderson Mesa proposal would take water from eight lakes (Yaeger, Mud, Pine, Camillo, Boot, Long Lake North, Breezy, and Ducknest Lakes) into the proposed pipeline from the Tremaine-Soldier Annex Project for M&I use at Flagstaff. The project would

require four pumping plants. Water would be available only during wet periods. It is estimated that 1,395 acre-feet per year of surface water could be obtained at a 1972 cost of $1.08 million (2).

Mormon Lake

Mormon Lake is located in Coconino County within the Coconino National Forest, twenty miles southeast of Flagstaff in Sections 4, 5, 7, 8, 9, 10, 15, 16, 17, 18, 19, 20, 21, and 22, T18N, R9E. The lake is in a closed basin with the bottom near elevation 7,100. The drainage area is 36.7 square miles. The storage fluctuates widely depending upon runoff conditions. During drought years the basin will be almost completely dry. During wet years, the runoff captured can be as high as 15,000 - 16,000 acre-feet with a surface area of 4,500 acres.

In 1957, the City of Flagstaff applied for a permit to divert Mormon Lake water to Upper Lake Mary for M&I use by means of a tunnel. The permit was denied after protests by property owners, Coconino County, and others (3).

An alternative to the tunnel would be to trench through the ridge separating the Mormon Lake Basin from Walnut Creek and install a closed conduit (see Site Map 4-4). The conduit would be about 2,000 feet long requiring a maximum depth of cut of 93 feet to the bottom of the trench. An open channel cut would also be needed to connect Mormon Lake with Grass Flat. The channel would be about 10,000 feet long with an average depth of 10 feet.

Either structural proposal, the tunnel or the conduit cut through the ridge, would allow regulation of the water levels in Morman Lake via gravity release into Walnut Creek. The possibility of actual construction is slight. Opposition would be greater now than in 1957.

MISCELLANEOUS WATER DEVELOPMENT PROPOSALS

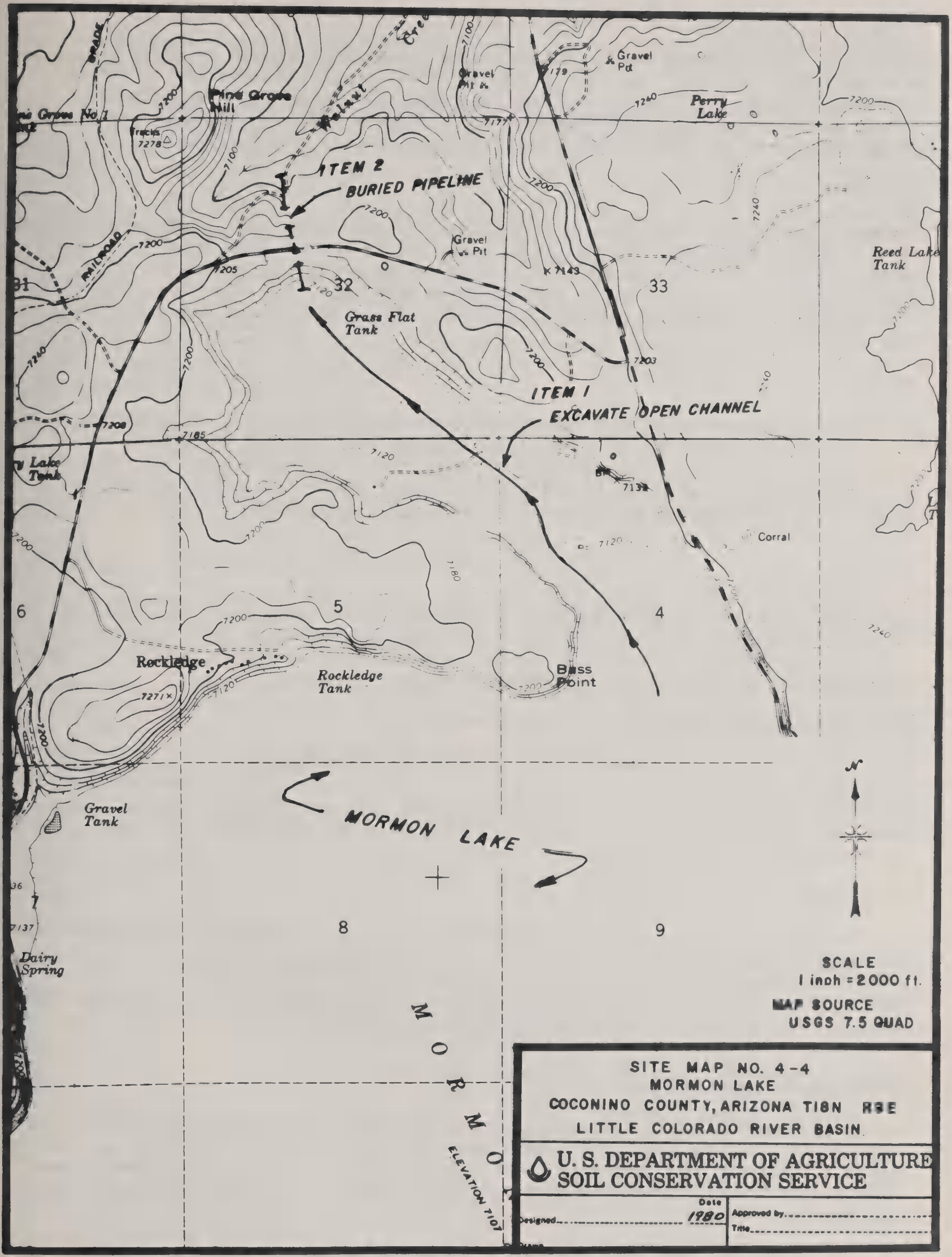
This section includes a brief discussion of 12 sites that were proposed for the construction of new reservoirs, either for irrigation or recreation. Several of these sites have either been judged unfeasible in the past or their feasibility is highly questionable.

Ashurst Lower

This site is located in Coconino County about 1/2 mile southeast of Ashurst Lake in Section 24, T19N, R9E. This site was proposed as a possible fish and wildlife lake by the Arizona Game and Fish Department in the 1960's. The proposed location is on Ashurst Run downstream from Coconino Dam. USDA reviewed this site in 1979. The site is of questionable feasibility because of limitation in water supply. Any excess runoff that is not trapped by Coconino Dam is diverted to fill Ashurst Lake.

Double Cabin

This site is located in Coconino County on an unnamed tributary to Chevelon Creek about 20 miles west of Heber in Section 11, T12N, R13E. It was considered as a fish and wildlife reservoir in the 1960's by the Arizona Game and Fish Department; however, detailed planning was never done because of questionable water yield and high costs.


ITEM 2
BURIED PIPELINE
ITEM 1
EXCAVATE OPEN CHANNEL
Pine Grove Hill
Gravel Pit
Perry Lake
Reed Lake Tank
Grass Flat Tank
RAILROAD
Corral
Rockledge
Rockledge Tank
Bass Point
Gravel Tank
Dairy Spring
MORMON LAKE
ELEVATION 7107
31
32
33
6
5
4
8
9
SCALE
1 inch = 2000 ft.
MAP SOURCE
USGS 7.5 QUAD
SITE MAP NO. 4-4
MORMON LAKE
COCONINO COUNTY, ARIZONA T18N R8E
LITTLE COLORADO RIVER BASIN
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed
Date
1980
Approved by
Title

Ellsworth Reservoir

Records on file with the Office of Dam Safety, Arizona Department of Water Resources, show a 1960 proposal to construct a 140 acre-feet irrigation reservoir on Concho Creek in Section 34, T14N, R26E. This location is about seven miles north of Concho and about 1/2 mile upstream from U. S. Highway 180. The proposal was dropped after downstream interests filed a water rights protest.

Empire Lake

Records on file with the Office of Dam Safety, Arizona Department of Water Resources, show a 1973 proposal to construct an 85 acre-feet recreation lake about two miles north of Concho on Weir Draw, a tributary to Concho Creek, in Section 29, T13N, R26E. This lake was proposed by a subdivision developer. The water level was to be supplemented by pumping of groundwater. The proposal was dropped because of financial difficulties.

Mineral

This site is located in Apache County on Mineral Creek about five miles northwest of Greens Peak in Section 7, T9E, R26E. The Arizona Game and Fish Department had a proposal to construct a fish and wildlife reservoir at this site but the plans were not pursued because of potential hazard to Arizona native trout in upper Mineral Creek. The site was not investigated by USDA and its physical feasibility has not been determined.

Pinedale

This site is located in Navajo County on Mortensen Wash about two miles northeast of Pinedale in Section 28, T11N, R20E. In the early 1960's the Arizona Game and Fish Department surveyed and drilled the site for a possible recreation reservoir. It was abandoned in 1964 because of potential seepage problems.

Rim Dam (Hole-In-Ground, Woods Canyon Diversion)

This site is located in Coconino County on the Mogollon Rim about two miles west of Woods Canyon Lake in Section 15, T11N, R13E. In 1962, the Arizona Game and Fish Department investigated this site as a potential fish and wildlife reservoir that would also permit water diversion over the Rim into the Verde River Drainage. The project is currently inactive.

Travertine

Records on file with the Office of Dam Safety, Arizona Department of Water Resources, show a 1959 proposal to construct a 23 foot high dam on Zuni Wash about five miles east of its junction with the Little Colorado River. The proposed location is in Apache County in the NE 1/4, SW 1/4, Section 3, T14N, R26E. The proposed dam would store 5,160 acre-feet of water for irrigation. This structure has not been constructed. The degree of site investigation is unknown.

Vernon (Jack Porter)

Vernon is a small farming community located in Apache County about 30 miles west of Springerville. Since 1940, or perhaps earlier, there have been proposals to construct a reservoir near Vernon on Mineral Creek, Pulcifer Creek or Sepulveda Creek (Jack Porter Creek). There are five different sites that have been proposed. None have been constructed.

In 1940, the Soil Conservation Service surveyed and prepared preliminary plans for a 950 acre-feet irrigation reservoir located at the junction of Sepulveda Creek and Pulcifer Creek in the NW 1/4, Section 27, T10N, R25E.

In 1942, the Soil Conservation Service surveyed and prepared preliminary plans for an irrigation reservoir, called Jack Porter Reservoir, on Sepulveda Creek in the SE 1/4, Section 28, T10N, R25E. The proposal was to divert water to the reservoir from Pulcifer Creek; the point of diversion being in the SW 1/4, Section 34, T10N, R25E.

A listing of possible fish and wildlife reservoirs prepared by the Arizona Game and Fish Department in the early 1960's proposed a Vernon Dam to be located on Pulcifer Creek in Section 12, T10N, R25E. The dam would be 65 feet high storing up to 2,200 acre-feet. The location as listed would place the dam on Mineral Creek north of U.S. Highway 60 instead of on Pulcifer Creek. The files of the Arizona Game and Fish Department have 1965 correspondence relating to another Vernon Dam located south of Vernon on Pulcifer Creek. The proposal was for a 60 foot high dam storing 1,000 acre-feet. The location of this site is not given; however, it is probably in Section 34, T10N, R25E.

In 1979, the Soil Conservation Service investigated a proposed irrigation reservoir site on an unnamed tributary to Anderson Lake in the NW 1/4, Section 29, T10N, R25E. The site was rejected because of storage limitations and poor geology. The Arizona Game and Fish Department cannot give a favorable recommendation to the Vernon sites because of the possible threat to Arizona native trout in upper Mineral Creek (1).

INVENTORY OF EXISTING RESERVOIRS AND LAKES

The major reservoirs and lakes within the Basin are listed in Table 4-3, which shows 210 sites, including 175 in Arizona and 35 in New Mexico. Their location is shown on the map titled "Existing Reservoirs and Lakes," following Table 4-3.

There are numerous stock ponds, closed basins and other intermittent storage sites within the Basin that are not included on Table 4-3. Judgmental decisions were made as to which sites to include. In general, Table 4-3 includes practically every embankment type storage site with a storage capacity of 10 acre-feet or greater and most of the natural lakes.

The data shown in Table 4-3 was compiled from several sources, including a review of literature, from the files of state and federal agencies, and from interviews and correspondence with knowledgeable individuals. This data was not compatible from all sources. Such items as drainage area, height, capacity, surface area, etc. varied. This is to be expected. The data presented is USDA's best estimate of present conditions.

The following comments relate to specific columns of Table 4-3:

Drainage Areas - The drainage areas were determined by planimeter from U.S. Geological Survey quadrangle maps or from state highway quadrangle maps.

Storage Capacity - USDA has not made a concerted effort to reconcile possible differences in storage capacity as shown in Table 4-3 with what may be a legal storage right. All users are urged to seek further information on water rights as appropriate.

Land Status - The land status was determined by USDA concurrent with preparation of the Land Ownership and Administration Map for this Basin study.

Irrigation Water User - For those structures with irrigation water use as a purpose, the data on "Irrigation Water User" in Arizona was supplied by Soil Conservation Service Field Offices; in New Mexico by the State Engineer's Office.

Needs - In some instances, the "Needs" column of Table 4-3 shows various needs, including items such as fencing and islands for wildlife, dam repair, recreation facilities, etc. This determination is purely judgmental, and does not recognize all opinions as to what may be needed at a particular site. A full listing of all needs for all purposes, several of which may be conflicting, is beyond the scope and intent of the Table. Similarly, the omission of any "needs" for a particular site does not mean that site improvements are not needed.

TABLE 4-3
Existing Reservoirs & Lakes
Little Colorado River Basin

Map No.	Name	Location	Stream or Tributary	Drainage Area (Sq. Mi.)	Type of Structure	Primary Uses 1/	Height or Water Depth (Ft.) 2/	Capacity (AF)	Surface Area (Ac.)	Land Status	Irrigation Water User 8/	Needs	Remarks
	APACHE COUNTY, ARIZONA												
1	Anderson Lake	S16,T10N,R25E	Offstream-Sepulveda Cr.	5.4 6/	Basin	W	4.0	38	19	State		Fencing & potholes for waterfowl	Intermittent storage. Ditch from Mineral Creek.
2*	Atcheson Reservoir Bailey 9/	S13,T7N,R28E S8,T7N,R30E	Water Canyon Tr.-Riggs Creek	2.5	Earth Earth	I,St,Se St.	8.0	205	61	USFS USFS	Slade & Fowler		Shallow depth. Flow diverted from Rudd Lake.
3	Becker Lake	S20,T9N,R29E	Offstream-Little Colo.	8.0	Earth	I,R,W	22.0	1,338	96	State (AZ G&F)	Hooper		Filled by ditch from Little Colorado.
4	Beckers Reservoir	S31,T9N,R31E	Tr.-Coyote Creek	17.3	Earth	St, Se	18.0	250	60	Private			Dam is breached. New dam downstream.
5*	Boynton Lake (Scout)	S4,T9N,R26E	Tr.-Mineral Creek	9.7	Earth	W, R	20.0	100	15	Private (T. Roosevelt Council-BSA)		Sealing, fencing & islands for waterfowl	
6*	Bunch Reservoir	S36,T8N,R27E	Tr.-Benny Creek	32.2 6/	Earth	I,W,R	22.0	612	44	USFS	Round Valley Water Users		Filled by ditch from Little Colorado.
7*	Carnero 10/	S6,T8N,R27E	Carnero Creek	3.4	Basin&Earth	I,W,R	8.0	375	65	USFS	Butler & Wiltbank	Relocate spillway, enlarge filler ditch, fencing & islands	
8	Chilcott No. 1	S20,T12N,R25E	Tr.-Manuel Seep Draw	2.0	Earth	Se, St	15.0	7	1	Private&State			
9	Chilcott No. 2	S11,T12N,R25E	Tr.-Mail Station Draw	0.3	Earth	Se, St	15.0	5	1	Private			
10	City of St. Johns No. 1	S31,T13N,R28E	Offstream-Little Colo.	0.5	Earth	R,W,S	9.0	15	5	Private (City)		Could develop city park	Filled from Lyman Canal
11	City of St. Johns No. 2	S31,T13N,R28E	Offstream-Little Colo.	0.5	Earth	R,W,S	18.0	18	3	Private (City)		Could develop city park	Filled from Lyman Canal
12*	Colter (River No. 1) 13/	S3,T6N,R27E	East Fork of Little Colo.	6.5	Earth	I,R,W	24.0	724	100	USFS	Lyman Water Co.	Fencing for wildlife	
13*	Concho Lake	S7,T12N,R26E	Concho Creek	4.5	Earth	I,R,W	28.0	1,197	155	Private, (AZ, G&F)	Concho Water Co.	Aquatic weed control	
14	Conservation Reservoir No. 1 (H-V)	S34,T8N,R31E	Offstream-Coyote Creek	15.0 6/	Basin&Earth	I,W	20.0	239	33	Private & USFS	H-V (Scarlett)	Fencing & islands for waterfowl	Ditch from Coyote Creek
15	Conservation Reservoir No. 2	S22,T8N,R31E	Offstream-Coyote Creek	21.0 6/	Earth	I,W,St	20.0	180	20	Private	H-V (Scarlett)	Fencing & islands for waterfowl	Ditch from Coyote Creek
16*	Coronado Generating Sta.	S5,T13N,R29E	Offstream-Little Colo.	--	Earth	C	53.0	4,650	263	Private			Power plant cooling pond
17	Crosby Development	S26,T8N,R27E	Tr.-Hall Creek	0.5	Earth	W,St,Se	20.0	9	1.5	Private			
18	Double Ponds	S6,T7N,R28E	Tr.-Little Colorado	0.9	Earth	W,St,Se	10.0	6	2	Private (Phelps-Dodge)		Aquatic weed control or enlargement	
19	Dora Y. Greer (D.Y.G.)	S35,T13N,R27E	Tr.-Big Hollow Wash	0.5	Earth	I, St, Se	12.0	20	5	State	W. Greer	Enlargement	
	Eagar-Slade (See Slade)												
20*	Ellis-Wiltbank	S14,15,T8N,R27E	Offstream-Fish Creek	16.5 6/	Basin&Earth	I,W	18.0	205	26	State & USFS	Butler & Wiltbank	Fencing for wildlife	Ditch from Fish Creek
21	Finch-Giles (Lee Burgess)	S1,T6N,R29E	Offstream-Nutrioso Cr.	2.0	Earth	I,W,R	10.0	32	8	Private	Finch & Giles	Enlargement, aquatic weed control, fencing & islands	Ditch from Colter Creek
22	Ganado Lake	S24,T27N,R26E	Tr.-Pueblo Colorado	230.0	Earth	I,W,R	18.0	3,800	360	Indian Trust (Navajo)	Navajos	Dam repair, enlargement, recreation facilities, aquatic weed control	1000 AF normal storage
23	Geneva	S6,T7N,R27E	Horsecamp Draw	1.0	Basin&Earth	I,W	14.0	150	57	USFS	Butler & Wiltbank	New headgate, fencing & islands	
	Glen Coe (See McKay)												
24*	Glen Livet	S½S6,T7N,R30E	Tr.-Rudd Creek	2.8	Earth	I,W	13.0	30.0	6	USFS	White Mtn. Hereford Ranch		
25	Greer No. 1	S14,23,T13N,R27E	Big Hollow Wash	1.4	Earth	St, Se	12.0	7.0	2	Private&State			
26	Greer No. 2	S13,T13N,R27E	Big Hollow Wash	1.7 0.3**	Earth	St, Se	10.0	16.0	4	State			In series with Greer No. 1
	H-V (See Con. Res. No. 1)												

TABLE 4-3
Existing Reservoirs & Lakes
Little Colorado River Basin

Map No.	Name	Location	Stream or Tributary	Drainage Area (Mi.)	Type of Structure	Primary Uses	Height or Water Depth (Ft.)	Capacity (AF)	Surface Area (Ac.)	Land Status	Irrigation Water User	Needs	Remarks
27	Harris Lake	S30,T9N,R26E	Tr-Mineral Creek	0.3	Basin	[redacted]	5.0	30.0	15	Private		Fencing & Islands	
28	[redacted]	S18,T7N,R28E	Tr-South Fork	0.5	Basin	[redacted]	4.0	74.0	37	USFS		Fencing for waterfowl	Intermittent storage
29	[redacted]	S26,T8N,R27E	Tr-Hall Creek	0.5	Earth	St, Se, W	12.0	8.0	2	Private			
30	[redacted]	S7,T25N,R30E	Black Creek	0.2	Earth	St, W, R	10.0	20.0	5	Indian Trust (Navajo)		Dam repair, improved access	
31*	[redacted] Wallow	S19,T7N,R28E	Tr-South Fork	1.1	Basin	I,W	6.5	80.0 5/	80	USFS	Lyman Water Co.	Fencing and Islands	Intermittent Storage
32	Hulsey [redacted]	S10,T6N,R30E	Hulsey Creek	2.5	Earth	R,W	24.0	40.0	5	USFS		Riprap on Dam	
33*	Jarvis	S20,T7N,R30E	Offstream - Colter Creek	16.5 0.8**	Earth	I,W	15.0	120.0	6	Private	L. Rogers	Islands for Waterfowl	Ditch from Colter Creek
34	Lake Hole	S24,T10N,R24E	Tr-Ortega Draw	6.0 6/	Basin	R,W	20.0	180.0	18	Private			Filled by Collector Ditch
	Lee Burgess(See Finch Giles) L.L. Martin 11/	S29,T7N,R30E	Nutrioso Ck.										
35*	Lee Valley 7/	S4,T6N,R27E	East Fork-Lit. Colorado	1.7	Earth	I,R,W	20.0	400.0	45	USFS	AZ G&F		Irrigation not in [redacted]
36	Little Dogie	S11,T10N,R25E	Mineral Creek	10.0 6/	Earth	I,W	12.0	8.0	2	Private	H. Butler	Aquatic Weed Control Fencing and Islands	
37	Little George Eagar (Rencher No.5)	S7,T7N,R29E	Tr-Water Canyon	0.4	Earth	I,Se,St	11.0	26.0	6	USFS	L. Slade		
38	Little Ortega	S2,T11N,R25E	Mineral Creek	97.0	Basin	I,St,W	10.0	1,050.0	225	Private & State	Chilicott		Mineral Creek ends. Intermittent Storage
39	Little Reservoir	S33,34,T13N,R28E	Offstream - Little Colo.	1.0	Earth	I,R,W	18.0	585.0	65	Private	St.Johns Irr.Co.	Seepage Control on Dam	Ditch from Lyman Canal and Little Colorado River
40*	Lyman Lake	S4,T11N,R28E	Little Colo.	790.0	Earth	I,R,W,Se	80.0	30,600.0	1,400	Private, BLM, & State	Lyman Water Co.	Control of Sediment Inflow, Seepage, Salt Cedars	
41*	Maxican Hay	S2,T7N,R28E	Joe Baca Draw	3.6	Basin & Earth	I,R,W	11.0	821.0	164	USFS	Lyman Water Co.	Fencing & Islands	
42	[redacted]ican Ranch Tank	S16,T10N,R28E	Virgil Run	1.5	Earth	Se,St,W	10.0	20.0	4	State			
43*	McKay (Glen Coe)	S1,T7N,R29E	Offstream - Rudd Creek	13.0 6/	Earth	I,W	15.0	150.0	20	Private	White Mt.Hereford Ranch		Ditch from Rudd Creek
44*	Nel[redacted] Reservoir	S28,T8N,R30E	Nutrioso Cr.	86.8	Basin & Earth	I,W,R	26.0	530.0	100	USFS	L.Gibbons & AZ.G&F	Fencing & Islands	
45*	Norton Reservoir 7/	S29,T8N,R27E	Fish Creek	2.4	Basin & Earth	I,W	9.5	232.0	56	USFS	Butler [redacted] Wiltbank	Fencing	Storage fluctuation
46*	[redacted]rioso Dam	S31,T7N,R30E	Auger Creek	12.5	Earth	I,W	10.0	145.0	31	Private [redacted] USFS	M.Hall & Others	Fencing & Islands	
47	Ortega Spring Lake	S10,T12N,R26E	Tr-Concho Cr.	0.7	Earth	W	12.0	16.0	4	Private		Sediment removal, aquatic weed control, fencing & islands.	
48	Patterson	S16,T13N,R25E	Tr - Oso Draw	19.0	Earth	St,W,Se	30.0	280.0	28	State			
49	Patterson	S21,T13N,R25E	Mail Sta.Draw	3.6	Earth	St,Se,W	20.0	93.0	14	Private			
50*	Pool Corral No. 3	S29,30,T7N,R28E	Tr-South Fork	0.4	Basin & Earth	I, W	14.0	993.0	72	USFS	Lyman Water Co.	Fencing [redacted] Islands	Intermittent Storage
51	Pratt Lake	S3,T7N,R31E	Tr-Coyote Crk.	2.5	Basin	W	-	35.0	7	USFS		Fencing [redacted] Islands	
52	Reagan Reservoir	S2,T7N,R30E	Offstream - Davis Creek	6.0 6/	Basin	W	-	188.0	50	USFS		Fencing [redacted] Islands	Ditch f[redacted] Davis Creek
53	Red Lake	S20,T20N,R21W(NM) 3/ S32,T3N,R5W(AZ)	Tr- Black Cr.	108.1	Earth	I,R,W	22.0	9,885.0	908	Indian Trust (Navajoe)	Navajos	Recreation facilities	On AZ-NM line, Water Diverted from Tohdildonih Wash with D.A. - 76 mi.^{2}
54	Riggs Creek No.2	S24,T7N,R29E	Ri[redacted] Creek	3.5	Earth	W	9.0	80.0	28	USFS & Private		Fencing & Islands	Nearly filled with sediment
	River No.1(See Colter)												
55*	River Reservoir No.3	S6,T7N,R28E	East Fork - Little Co.Rv.	35.0	Earth	I,R,W	50.0	1,669.0	127	USFS	Round Valley Water Users		
56	[redacted] Pond	S6,T7N,R30E	Offstream - Rudd Creek	0.1	Earth	St,Se,W	20.0	20.0	2	Private			Ditch from [redacted] Creek
	Rencher No.5(See Little George Eagar)												
57 *	Rogers(Wilkens & Sharp)	S3,T6N,R29E	Colter Creek	5.0	Earth	I,W	11.5	183.0	10	USFS	Rogers & Spillman	Fencing	
58	Rudd	S23,T7N,R28E	Water Canyon	1.8	Earth	W	3.0	-	28	USFS		Repairs on Dam	Dam abandoned. Good potential for waterfowl.

TABLE 4-3
Existing Reservoirs & Lakes
Little Colorado River Basin

Map No.	Name	Location	Stream or Tributary	Drainage Area (Mi.)	Type of Structure	Primary Uses	Height or Water Depth (Ft.)	Capacity (AF)	Surface Area (Ac.)	Land Status	Irrigation Water User	Needs	Remarks
59	Russel	S19,T7N,R29E	Water Canyon	0.5	Earth	I	3.0	138.0	46	USFS	Slade & Fowler	Fencing & Island	
60	Salado Springs	S17,20,T12N,R28E	Little Colo.	2.0**	None	St,Se,W	-	-	130	Private			Marsh Area, no storage, Excellent Wildlife Habitat
61	San Salvador	S19,T7N,R29E	Tr - Rudd Creek	0.6	Earth	I,W	9.0	102.0	34	USFS	White Mtn.Hereford Ranch	Fencing & Islands	
	Scout Lake (See Boynton)												
62*	Sheep Springs	S31,T8N,R27E	Fish Creek	3.0	Earth	St, W	28.0	390.0	43	USFS			Embankment is a highway fill, Does not retain water.
63*	Slade (Eagar-Slade)	S18,T7N,R29E	Water Canyon	3.8	Earth	I, St	18.0	522.0	62	USFS	Slade & Fowler		
64	Snake Ranch	S10,15,T12N,R26E	Tr-Concho Cr.	2.8	Earth	St,Se,.W	12.0	72.0	18	Private		Sediment removal	Seldom holds water
65	Sponseller Lake	S30,T10N,R24E	Tr-Rocky Arroyo	2.5	Basin	W	2.0	68.0	34	Private		Fencing & Islands	
66	St. Josephs	S19,T7N,R29E	Tr-Rudd Creek	0.2	Earth	I,W	4.0	52.0	26	USFS	White Mtn.Hereford Ranch	Fencing & Islands	Intermittent storage
67	St. Marys	S19,T7N,R29E	Tr-Rudd Creek	0.4	Earth	I,W	12.0	120.0 5/	23	USFS	White Mtn.Hereford Ranch		
68	Sunnyside	S30,T8N,R27E	Fish Creek	6.7	Earth	W	20.0	400.0	38	USFS		Potential waterfowl habitat	Does not retain water because of failed Hollow Log outlet pipe
69	The Clara	S10,11,T10N,R25E	Sepulveda Cr.	51.4 6/	Basin	St,Se,W	4.0	72.0	36	Private		Fencing & Islands	
70	Towser	S2,T7N,R31E	Tr-Coyote Cr.	1.5	Earth	I	10.0	20.0	4	Private	C. Simpson		
71	Trinity	S6,T7N,R30E	Rudd Creek	16.8 6/	Earth	I,W	14.0	43.0	10	Private	White Mtn. Hereford Ranch	Sediment removal, seepage control	Ditch from Rudd Creek, D/S of McKay Reservoir
72	Trout Lake	S28,T2N,R6W 3/	Bonito Creek	26.0	Earth	St,W,R	15.0	60.0	20	Indian Trust (Navajo)		Dam repair, seepage control, improved access	Intermittent storage
73	Trout Pond	S1,T7N,R29E	Milligan Cr.	0.1	Earth	St,Se,W	15.0	5.0	1	Private		Seepage control	
74	Tunnel Reservoir	S1,T7N,R27E	Offstream - Little Colo.	31.3 6/	Earth	I, R, W	27.2	694.0	44	USFS	Round Valley Water Users		Ditch from Little Colorado
	Tyler (See Carnero)												
	Udall (See Zion)												
75	Unknown	S19,T14N,R26E	Tr-Little Co.	4.0	Earth	St, W	12.0	8.0	2	Private			
76	Unknown	S7,T14N,R28E	Tr - Zuni	1.0	Pit	St,Se	15.0	7.0	1	Private			
77	Unknown	S30,T12N,R28E	Tr-Little Co.	0.5	Pit	St,Se	15.0	5.0	1	Private			
78	Unknown	S30,T12N,R28E	Tr-Little Co.	1.0	Earth	St,Se	12.0	7.0	2	Private			
79	Unknown	S18,T7N,R30E	Tr-Riggs Cr.	0.2	Earth	St. Se	4.0	8.0	2	USFS			
80	Unknown	S17,T6N,R29E	Tr-Colter Cr.	0.3	Earth	W	4.0	48.0	24	USFS			Dam washed out, potential wildlife habitat
81	Vigil	S9,T10N,R28E	Vigil	25.3	Basin & Earth	St,Se,W	5.0	27.0	9	Private & State		Enlargement	Water from Wiltbank Springs
	Wilkins & Sharp (See Rogers)												
82*	Water Canyon (Canyon)	S13,T7N,R28E	Water Canyon	4.0 0.2**	Earth	I,St,Se	14.0	65.0	9	USFS	Slade & Fowler		
	Westside 12/	S6,T8N,R29E	Little Colo.	Offstream	Basin								
83	Wiltbank No.1	S36,T9N,R27E	Tr-Carnero Cr.	2.5	Earth	I,St,W	20.0	7.0	4	State	J. Wiltbank		Ditch from Fish and Carnero Creeks
84	Wiltbank No.2	S31,T9N,R28E	Tr-Carnero Cr.	3.3 0.8**	Earth	I,St,W	30.0	13.0	8	Private	J. Wiltbank		Ditch from Fish and Carnero Creeks
85	Wiltbank No.3	S31,79N,R28E	Tr-Carnero Cr.	4.0 0.7**	Earth	I,St,W	25.0	15.0	3	Private	J. Wiltbank	Seepage Control	Ditch from Fish & Carnero Cr.
86	Wiltbank No.4	S31,T9N,R28E	Tr-Carnero Cr.	4.2 0.2**	Earth	I,St,W	20.0	8.0	5	State	J. Wiltbank	Dam Repair	Ditch fr. Fish & Carnero Cr.
87*	White Mtn.Reservoir	S17,T7N,R27E	Hall Creek	5.5	Earth	I,R,W	16.0	2390.0	450	USFS	Round Valley Water Users	Fencing & Islands	Shallow lake, High losses.
88*	Zion (Udall)	S21,T14N,R27E	Little Co.	3,530	Earth	St,Se	24.0	[illegible]	640	Private & State			Exceptionally efficient in trapping sediment

TABLE 4-3
Existing Reservoirs & Lakes
Little Colorado River Basin

Map No.	Name	Location	Stream or Tributary	Drainage Area (Mi.)	Type of Structure	Primary Uses	Height or Water Depth (Ft.)	Capacity (AF)	Surface Area (Ac.)	Land Status	Irrigation Water User	Needs	Remarks
	NAVAJO COUNTY ARIZONA												
	Baird (See Love Lake)												
[redacted]	Big Mountain Dam	S25,T32N,R17E	Offstream-Dinnebito Wash	211.0	Earth	Se, F	60.0	1,600.0	300	Indian Trust (Navajo)			Complete silted in
90	Bills Lake	S7,T11N,R22E	Tr-Silver Cr.	0.2	Earth	R, W	15.0	60.0	5	Private		Work on embankment & spillway	
91*	Black Canyon Lake 7/	S24,T11N,R15E	Black Canyon Creek	5.8	Earth	R, W	69.0	1,581.0	78	USFS			Aquatic weed problem at times
92	Chevelon Diversion	S23,T18N,R17E	Chevelon Cr.	815.7	Concrete	W, I(not in use)	6.0	30	5	Private	Chevelon Irrig. Co.		Irrig. diversion not in use. D.A. includes 38.2 sq.mi.non-contributing.
	Chevelon Cr. Wildlife Area (see Hugo Meadows)												
93*	Cholla-Bottom Ash Pond	S13,23,24,T18N, R19E	Offstream-Tanner Wash	0.0	Earth	D	70.0	2,300.0	88	Private			Power plant ash disposal
94*	Cholla-Fly Ash Pond	S30,T18N,R20E	Offstream-Little Colo.	2.5	Earth	D	80.0	16,500.0	440	Private			Power plant ash disposal
95*	Cholla Lake	S25,T18N,R19E	Offstream-Little Colo.	0.0	Earth	R, W, C	5.0	1,800.0	360	Private			Power plant cooling pond
96*	Clear Creek Res.	S10,T18N,R16E	Clear Creek	608.0	Masonry	I, R, W	13.0	350.0	50	State,Private	City of Winslow	Sediment removal	New dam being constructed downstream
	Daggs (see White Mountain Lake)												
97	Decker Pond	S19,T12N,R22E	Walnut Draw	8.7	Earth	R, W	20.0	100.0	10	Private			Excellent wildlife habitat
[redacted]	Dry Lake	S2,T14N,R18E	Phoenix Park Wash	124.0	Basin	D	-	WNK	1,500	State,Private		Treatment for strong odors	Waste water from pulp mill
99	Duck Lake	S13,T11N,R22E	Silver Creek	62.0	Masonry	R, W	20.0	200.0	14	Private			Excellent wildlife habitat
100*	Five Mile Wash	S29,T17N,R21E	Five Mile Wash	6.1	Earth	St, Se	25.0	15.0		State(ADOT)			Highway fill
101*	Fools Hollow 7/	S12,R10N,R21E	Showlow Cr.	109.0	Earth	R, W	60.0	3,217.0	149	Private,State		Aquatic weed control	
102	Jacks Lake	S5,T12N,R21E	Offstream-Silver Creek Dobson Wash	0.0	Earth	R, W	23.0	20.0	1	Private			Supplied by well from ground water
	Jacques (see Showlow)												
103	Hugo Meadows (3 ponds) (Chevelon Wildlife)	S23,26,T18N, R17E	Offstream-Chevelon Cr.	22.8	Earth	W	1,1,2	10,60,100	10,50,60	State (AZ G&F)			Wildlife area, water obtained by pump from Chevelon Creek
104	Kaufman No. 2	S4,T18N,R16E	Salt Creek	321.8	Masonry	R, Se	10.0	--	--	BLM			Completely silted in
105	Kaufman Recreation	S4,T18N,R16E	Salt Creek	321.8	Earth	R	10.0	115.0		Private			Filled by Diversion fr.Kauf-[redacted] #2.Structure has failed.
106	Keems Canyon Lake	S23,T28N,R20E	Keems Canyon Wash	5.0	Earth	R, W, F	50.0	75.0	2	Indian Trust (Hopi)			Completely silted in.
107	Lake Maho	S23,T28N,R20E	Keems Canyon Wash	5.0	Earth	I, F, W	60.0	130.0	3	Indian Trust (Hopi)			Silted in
	Lakeside (see Rainbow)												
108	Lakeside No. 1	S26,T9N,R22E	Walnut Creek	10.0	Concrete	R, P(not in use)	19.5	--	--	Private			Originally for power. Structure has failed.
109	Lakeside Coffer Dam	S23,T9N,R22E	Walnut Creek	11.5	Earth	I, R	14.0	3.0	1	Private	Showlow Irrig. Co.		Irrigation diversion dam
110*	Lake of the Woods	S23,T9N,R22E	Walnut Creek	11.6	Earth	R, W	14.0	120.0	20	Private		Aquatic weed control	
111	Little Mormon	S12,T10N,R22E	Tr-Silver Cr.	33.7 6/	Basin	R, W	38.0	1,400.0	125	USFS			Ditch from Rocky Arroyo. Storage rights are held by the Silver Creek Irrigation District.
112	Long Lake	S10,T10N,R22E	Tr-Showlow Creek	9.5	Basin	St., W	--	1,500.0	372	USFS			Normally dry 8/
113*	Lone Pine	S14,T11N,R21E	Showlow Cr.	154.3	Earth	I,F,St,W	95.0	10,045.0	350	USFS	Silver Cr. Irrig.Dist. 8/	Seepage control	High seepage losses
114	Love Lake (Baird)	S33,T12N,R22E	Walnut Draw	4.7	Earth	I, W	11.0	12.0	20	Private	J. Baird		Good wildlife habitat
115	Martinez Lake	S28,T11N,R23E	Offstream-Brown Creek	52.5 6/	Earth	I,St,W	12.0	500.0	100	Private	Silver Cr. Irrig.Dist.	Silt removal & enlargement	Ditch from Brown Cr.,approx. 51.0 sq. mi. diverted
116	Markley	S31,T11N,R20E	Tr-Pinedale Wash	0.4	Earth	St	14.0	24.0	5	USFS			Normally dry

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Little Colorado River Basin

Map No.	Name	Location	Stream or Tributary	Drainage Area (Mi.)	Type of Structure	Primary Uses	Height or Water Depth (Ft.)	Capacity (AF)	Surface Area (Ac.)	Land Status	Irrigation Water User	Needs	Remarks
117	Mexican Lake	S11,T11N,R22E	Tr-Silver Cr.	134.5	Earth	I,F,W	12.0	1,100.0	128	Private	Silver Creek Irrigation District		Filled by high stage overflow from Daggs.
118*	Millet Swale	S20,T12N,R22E	Millet Swale	40.0	Earth	F,Se,St	25.4	1,342.0	199	Private		Repairs on outlet works	No permanent storage.
119	Ned Lake	S6,T10N,R22E	Tr-Showlow Cr	0.1	Basin	D			10	USFS			Disposal of sewage effluent from City of Show Low, AZ.
120	Pinetop Dam (Fish Hatchery)	S4,T8N,R23E	Billy Creek	2.0	Concrete	W	13.5			Private			Old fish hatchery not, in use.
121	Pine Lake	S5,T8N,R23E	Walnut Creek	1.0	Earth,Basin	I,R,W	12.0	450.0	54	Private	Showlow Irrigation Company		
122	Polacca Dam 2	S4,T27N,R18E	Polacca Wash	511.0	Earth	Se	47.0	3,000.0+		Indian Trust (Hopi)			Waterspreader. Completely filled with sediment.
123	Porter Spring Rearing Pond	S18,T9N,R23E	Porter Spring	1.0/0.4	Earth & Rock	I,W	19.0/15.0	15.0/25.0	1.5/2.5	Private	Showlow Irrigation Company	Work on emergency spillway (Dam 2)	
124*	Rainbow Lake (Lakeside)	S23,T9N,R22E	Walnut Creek	11.5	Earth	I,R,W	19.0	1,200.0	154	Private	Showlow Irrigation Company		
125	Rattlesnake Tank	S5,T11N,R20E	Rattlesnake Draw	2.4	Earthfill	St,W	11.0	2.0	1	USFS		Bank slopes flattened	
126	Rock Lake	S7,T11N,R22E	Tr.-Silver Creek	.3	Pit	R	10.0	15.0	2	Private			
127	Salmon Lake	S6,T11N,R22E	Tr.-Silver Creek	1.0	Earth	R	15.0	50.0	3	Private		Aquatic weed control	Steep embankment slopes.
128*	Scott Reservoir	S13,T9N,R22E	Porter Creek	34.5	Earth	I,R,W	37.0	1,450	75	Private	Showlow Irrig. Co.	Improved access & recreation	
129	Shafer Lake	S6,T11N,R22E	Tr.-Silver Creek	1.0	Earth	R	15.0	130.0	13	Private		Riprap on dam	Filled by well.
130*	Showlow Lake (Jacques)	S10,T9N,R22E	Showlow Creek	73.0	Earth & Rock	R, W	73.0	6,200	200	Private			Interbasin transfer of water to Salt River drainage, 1,070 AF dead storage.
131	Telephone Lake	S6,T10N,R22E	Tr.-Showlow Creek	0.2	Basin	D	--	--	23	USFS			Disposal of [redacted] effluent from City of Show Low, AZ.
132*	Trophy Lake	S7,T11N,R22E	Tr.-Silver Creek	0.26	Earth	R	20.0	70.0	6	Private			Membership fishing lake
133	Twin Dams	T28N,R21E	Keems Canyon Wash	3.9	Earth	F	30.0	1,500.0	150	Indian Trust (Hopi)			
134	Whipple Lake	S11,T10N,R22E	Tr.-Showlow Creek	35.2 1.5unc**	Basin	St, W	--	--	87	USFS			Normally dry, receives high stage overflow fr. Little Mormon.
135*	White Mountain Lake (Daggs)	S10,T11N,R22E	Silver Creek	134.5	Earth	I,R,W	60.0	3,500.0	283	Private			6.3 sq. mi. non-contributing.
136*	Woodland Reservoir	S31,T9N,R23E	Walnut Creek	5.3	Earth	I,R,W	18.0	140	23	USFS	Woodland Irrigation Company	Gate repair	Receives some water diverted from Billy Creek.
137	Woodruff Lake	S16,T16N,R22E	Offstream-Little Colo.	1.0	Basin & Earth	W				State			Normally dry. Use to be filled by ditch from Woodruff Reservoir.
138*	Woodruff Reservoir	S32,T16N,R22E	Silver Creek	942.0	Concrete	I,R,W	25.0	5.0	3	Private	Woodruff Irrigation District	Silt removal, recreation facilities	Old diversion dam for irrigation. Not in use.

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Little Colorado River Basin

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	Coconino County Arizona												
139*	Ashurst Lake 7/	S13,24,T19N,R9E	Tr.-Padre Canyon	1.8	Earth	R,W,St.	22.0	3,924	230	USFS			Overflow from Coconino Reservoir.
140	Babbitt Lake	S11,T25N,R5E	Tr - Cedar Wash	4.8	Earth,Basin	St,W	11.5	74	13	USFS			Very intermittent storage.
141*	Bear Canyon 7/	S20,T12N,R13E	Tr -Willow Creek	2.1	Earth	R,W	50.0	1,430	63	USFS			
142	Blue Lake	S20,T35N,R15E	Shonto Wash	156.0	Earth	St,Se	18.0	278	40	Indian Trust (Navajo)			
143*	Blue Ridge	S33,T14N,R11E	East Clear Creek	71.1	Concrete Arch	R,W,N	150.0	15,000	2-5	USFS & Private			Interbasin diversion to Verde River.
144	Canyon Diablo	T22N,R13E	Canyon Diablo	1137.0	Earth & Rock	R,St,W,F	29.0	4,700	450	Indian Trust(Navajo)			D.A.includes 451 mi^2 of non-contributing.Normally dry. Sinkholes in Reservoir Area.
145	Cheshire(Narrows Dam)	S5,T21N,R7E	Rio de Flag	44.0	Concrete Arch	St,W	20.0	65	1.3	Private		Silt removal and seepage control	Normally dry. Gates left open. Approx.18.5 sq.mi. non-contributing.
146*	Chevelon Canyon 7/	S14,T13N,R14E	Chevelon Creek	88.7	Earth	R,W	100.0	8,540	200	USFS			
147	City Park Lake	S16,T21N,R7E	Tr-Rio de Flag	53.8	Concrete	R	9.0	10	3	Private			
148*	Coconino Reservoir	S25,T19N,R9E	Ashurst Run	10.1	Earth	R,W	30.0	255	30	USFS			High stage storage can be diverted to Ashurst Lake.
149*	Continental No.1	S18,T21N,R8E	Tr-Rio de Flag	0.1	Earth	R,I	29.0	62	73	Private	Continental Country Club		Golf Course - Partial water supply from [redacted]age return
150*	Continental No.2	S19,T21N,R8E	Tr-Rio de Flag	0.6	Earth	R,I	40.0	565	36	Private	Continental Country Club		Golf Course -Partial water supply from sewage return
151*	Continental No.3	S19,T21N,R8E	Tr-Rio de Flag	0.2	Earth	R,I	34.0	195	12	Private	Continental Country Club		Golf Course-Partial water supply from sewage return
152	Cottonwood Pond Crisis Lake (See Snake No.2)	T32N,R11E	Tr-Moenkopi Wash	unknown	Earth	R,W	10.0	10	2	Indian Trust(Navajo)			Minor fishing use.Currently not managed.
153	Deer Lake	S25,T12N,R13E	TR-Chevelon Creek	0.3	Earth	W, St				USFS			
154	Flagstaff Res.No.2	S4,T21N,R7E	Offstream	0.0	Earth	W		152	10	Private			Flagstaff water supply
155	Flagstaff Res. No.3	S4,T21N,R7E	Offstream	0.0	Earth	S		148	10	Private			Flagstaff Water supply
156*	Hay Lake(See Tremaine Lake)	S30,T16N,R11E	Tr-Jacks Canyon	32.7 15.7	Basin	I,W		1,000	470	Private	Bar-T-Bar Ranch		Intermittent storage -combined with Tremaine Lake at extreme high stage.
157*	Kinnikinick Lake 7/	S35,T18N,R10E	TR-Kinnikinick Canyon	11.9 6/	Earth,Basin	R,W	18.0	2,820	145	USFS			Ditch from Kinnikinick Canyon Approximately 10.5 sq.mi. diverted.
158*	Knoll Lake 7/	S16,T12N,R12E	East Leonard Canyon	3.6	Earth	R,W	58.0 73.0	1,550	77	USFS			
159	Long Lake	S6,T16N,R11E	Tr-Jacks Canyon	2.0	Basin	W, St		1,200	270	USFS			Storage fluctuates. Overflow from Soldiers Annex.
160*	Lower Lake Mary	S18,T20N,R8E	Walnut Creek	87.5 32.7	Earth	R,W,St	21.0	8,600	100	USFS			
161	Meadow Lake	S29,T18N,R9E	Fulton Canyon	13.1	Earth	R,W,St.	8.5	45	10	Private			
162	Moonlight Bay	S17,T17N,R15E	Tr-Jacks Canyon	13.7	Earth,Basin	St,W			50	Private &State			Intermittant Storage
163	Mormon Lake	S8,9,T18N,R9E	Walnut Creek	36.7	Basin	R,W	6.0	15,000	600-3000	USFS			Storage Fluctuates
164*	Morton Dam	S36,T18N,R10E	Tr-Kinnikinick Canyon	12.0 6/	Earth	I,W,St.	18.0	285	29	USFS	H. Metzger		Minor irrigation for pasture approximately 5 mi. downstream
165	Mud Lake	S20,T18N,R10E	Tr-Kinniki-nick Canyon	2.0	Earth	W,St	6.0	204	88	USFS			Intermittent storage. Dam is road fill.
	Narrows (See Cheshire)												

TABLE 4 – 3
Existing Reservoirs & Lakes
Little Colorado River Basin

Map No.	Name	Location	Stream or Tributary	Drainage Area (Mi.)	Type of Structure	Primary Uses	Height or Water Depth (Ft.)	Capacity (AF)	Surface Area (A.)	Land Status	Irrigation Water User	Needs	Remarks
166	Pasture Canyon	S21,T32N,R11E	Tr-Moenkopi Wash	1.9	Rock	I,R,St.	13.0	250	36	Indian Trust (Navajo)	Hopi Indians		Irrigation water used by Hopis at Moenkopi
	Sante Fe(See Walnut Canyon)												
167	Snake No.2(Crisis Lake)	S3,T16N,R10E	Canyon Diablo	8.8	Earth	St.,W	11.0	25	5	USFS			Original dam breached.
168	Soldiers Annex	S7,T15N,R11E	Tr-Jacks Canyon	28.4	Earth	I,W,St	30.0	1,886	140	USFS	Bar-T-Bar		Ditch from Sawmill and Diablo Canyons.
169	Soldiers Lake	S6,T16N,R11E	Tr-Jacks Canyon	27.9	Earth	I,W,St		550	40	USFS	Bar-T-Bar		Connected to Soldiers Annex.
	Tremaine(See Hay Lake)	S18,19,T16N, R11E	Tr-Jacks Canyon	17.0	Earth, Basin	I,W	26.0	5,000	500	Private	Bar-T-Bar		
170*	Upper Lake Mary	S27,T20N,R8E	Walnut Creek	54.8	Earth	R,W,S,St	38.5	11,470	600	USFS			Flagstaff Water Supply
171	Wallace Tank	S19,T19N,R12E	Wallace Canyon	28.1 2/	Earth	W,St	20.0	25	5	State - [illegible]			Stock tank for Buffalo Ranch, storage fluctuates. Approx. 19.8 sq.mi diverted.
172	Walnut Canyon(Santa Fe)	S31,T21N,R9E	Walnut Canyon	149.1	Masonry Arch	W	38.0	423	27	Private			Normally dry, inflow captured by upstream Lake Mary
173*	Willow Springs 1/	S29,T11N,R14E	Tr-Chevelon Creek	3.8	Earth-Rock	R,W	80.0	3,654	150	USFS			
174*	Woods Canyon 1/	S13,T11N,R13E	East Fork Chevelon Creek	9.8	Earth	R,W	49.4	1,013	50	USFS			
175	Youngs Canyon	S19,T21N,R9E	Youngs Canyon	15.3	Earth	St.,W	30.0	202		USFS			Dam failed December 1978.

TABLE 4-3
Existing Reservoirs & Lakes
Little Colorado River Basin

Map No.	Name	Location	Stream or Tributary	Drainage Area (Mi.)	Type of Structure	Primary Uses	Height or Water Depth (Ft.)	Capacity (AF)	Surface Area (Ac.)	Land Status	Irrigation Water User	Needs	Remarks
	McKINLEY COUNTY, NEW MEXICO												
176*	Asaayi Lake	T20N,R20W	Bowl Canyon Creek	21.0	Earth	R	18.0 av.	653.	36	Indian Trust (Navajo)	-	-	-
177*	Black Rock Reservoir	S17,T10N,R18W	Zuni River	653.0	Earth	I,R	14.0 max. 5.0 av.	2,600.	436	Indian Trust (Zuni)	Pueblo of Zuni	-	Enlargement Planned
178*	Bolton Reservoir	S24,T10N,R19W	Zuni River	7.7**	Earth	I,R	0.	0.	40	Indian Trust (Zuni)	Pueblo of Zuni	-	Breached
179*	Churchrock Tailings Dam	S2,T16N,R16W	Off Channel - Tr.Rio Puerco	0.	Earth	D	65.0	8,380.	160	Lease From Navajo Ind.	-	-	United Nuclear Uranium Mill. Tailing Dom
180*	Eustace Lake	S23,T10N,R19W	Zuni River	8.5**	Earth	R	15.0 max. 5.5 av.	270.	30	Indian Trust (Zuni)	-	-	Capacity Has Decreased Due To Silt
181*	Galestena #1A Reservoir (north)	S29,T9N,R17W	Upper Galestena Canyon	16.5	Earth	St,R	12.0 max. 7.0 av.	35.	10	Indian Trust (Zuni)	-	-	Widely Fluctuating Water Levels
182*	Kerr McGee Churchrock	S36,T17N,R16W	Off channel - Tr.Rio Puerco	0.	Earth	D	12.0 max	36.0	4	Lease From Navajo Ind.	-	-	Settling Ponds For Water From Mine Oper.
183	Knudson Lake	S30,T15N,R16W	Mink Ranch Canyon	32.0	Earth	F,R	10.0 max. 5.0 av.	40.0	8	Ft. Wingate Military Res.	-	-	Silted And Has Seepage Problems
184	Lake McFerren	S31,T14N,R16W	Rio Puerco	0.4	Earth	R	20.0 max. 12.0 av.	48.	4	Ft. Wingate Military Res.	-	-	Widely Fluctuating Water Levels
185	Marcotte Pond	S4,T14N,R16W	Milk Ranch Canyon	1.3	Earth	F,R	20.0 max. 10.0 av.	30.	3	Ft. Wingate Military Res.	-	-	-
186*	Mariano Lake	S27,T16N,R14W	Rio Puerco	53.3	Earth	St,R	15.0	1,172.0	80	Indian Trust (Navajo)	-	-	Water Supply Not Dependable Fisheries Lost in 1973
187*	McGaffy Lake	S10,T13N,R16W	Tampico Draw	6.3	Earth	[illegible]	8.0	110.0	14	USFS	-	-	Adm. by NM Game And Fish Dept.
188	Nutria Div. Reservoir	S18,T12N,R16W	Rio Nutria	86.8	Earth	I	5.0	100.0	21	Indian Trust (Zuni)	Zuni Indians	-	-
189*	Nutria Reservoir #2	S12,T11N,R18W	Rio Nutria	204.0	Earth	I,R	7.0	2,563.0	418	Indian Trust (Zuni)	Zuni Indians	-	-
190*	Nutria Reservoir #3	S34,T12N,R17W	Rio Nutria	140.0	Earth	I,W	6.0 max. 2.0 av.	460.0	265	Indian Trust (Zuni)	Zuni Indians	-	Badly Silted
191*	Nutria Reservoir #4	S33,T12N,R17W	Off channel - Rio Nutria	31.5**	Earth	R	13.0 max. 7.0 av.	880.0	88	Indian Trust (Zuni)	-	-	Water Diverted From Nutria #3
192*	Pescado Reservoir	S7,T10N,R16W	Cebolla Creek	103.0	Earth	I,R	9.0 max. 4.0 av.	720.0	120	Indian Trust (Zuni)	Zuni Indians	-	Water Diverted From Rio Pescado W/DA 207 Sq. Mi.
193*	Ramah Reservoir	S35,T11N,R16W	Cebolla Creek	50.0	Earth	I	10.0 av.	3,780.0	375	Private	Ramah Land and Irr. Company	-	Original Capacity Reduced Due To Silt
53*	Red Lake	(reported in Arizona; see Apache County listing)											
194*	Tekapo Reservoir	S10,T9N,R20W	Off channel - Zuni River	4.7**	Earth	I,R	3.0 av.	330.0	50	Indian Trust (Zuni)	Zuni Indians	-	Diverted From Zuni River Badly Silted
	VALENCIA COUNTY, NEW MEXICO												
195*	Atarque Lake	S12,T6N,R19W	Atarque Canyon	260.0	Earth	St.	0.	0.	730	Private	-	-	Dam Breached Orig. Capa. 6260 AF.
	Ashcroft (see Nicolls)												
196	Carpenter Lake	S14,T5N,R16W	Closed Basin	0.6	Pit within basin	St.	10.0 max.	3.0	0.5	Private	-	-	Dimensions Given Are For The Pit
197	Fence Lake	S28,T5N,R17W	Closed Basin	4.4	Pit within basin	St.	16.0 max.	5.0	0.7	Private	-	-	Dimensions Given Are For The Pit
198	Galestena #7 Reservoir (south)	S18,T8N,R17W	Upper Galostena Canyon	5.3	Earth	St.,R	10.0 max. 6.0 av.	60.0	22	Indian Trust (Zuni)	-	-	Widely Fluctuating Water Levels
199*	Nicolls Lake (Ashcroft)	S2,T8N,R15W	White Horse Draw	25.0	Earth	I	10.0 av.	625.0	60	Private	Individual	-	
200*	Ojo Caliente Reservoir	S20,T8N,R20W	Pulmasamo Wash	3.6	Earth	I,R	14. max. 7. av.	260.0	40	Indian Trust (Zuni)	Zuni Indians	-	Fed By Three Springs

TABLE 4-3
Existing Reservoirs & Lakes
Little Colorado River Basin

Map No.	Name	Location	Stream or Tributary	Drainage Area (Mi.)	Type of Structure	Primary Uses	Height or Water Depth (Ft.)	Capacity (AF)	Surface Area (Ac.)	Land Status	Irrigation Water User	Needs	Remarks
	CATRON COUNTY, NEW MEXICO												
201*	Blanes Lake	S30,T1N,R18W	Agua Fria Creek	61.0	Earth	St.	0	0	120	Private	-	-	Dam breached mostly silted in
202	Gatlin Lake	S11,T2S,R19W	Agua Fria Creek	76.0	Basin	St.	3.0 Av.	300.	100	Private	-	-	Playa Lake with intermittent storage
203*	Goat Ranch Det. #1	S21,T2N,R20W	Tr. Agua Fria Creek	2.0	Earth	F	20.0	86.	20	BLM	-	-	-
204*	Goat Ranch Det. #2	S20,T2N,R20W	Tr. Agua Fria Creek	1.4	Earth	F	19.0	152.	29	BLM	-	-	-
205*	Layton Det. #4	S3,T1N,R19W	Tr. Agua Fria Creek	2.0	Earth	F	22.0	79.	13	BLM	-	-	-
206*	Quemado Lake	S15,T2S,R16W	Largo Creek	63.0	Earth	R	60.0	2850.	136	USFS	-	-	Adm. by NM Game and Fish Dept
207*	Red Hill Det. #2	S13,T1N,R20W	Red Hill Draw	2.6	Earth	F	13.0	86.	14	BLM	-	-	Trib. to Agua Fria Creek
208*	Red Hill Det. #3	S18,T1N,R19W	Red Hill Draw	1.5	Earth	F	12.0	55.	11	BLM	-	-	Trib. to Agua Fria Creek
209*	Salt Lake	S30,T3N,R18W	Closed Basin	33.0	Basin	N	2.0 Av.	100.0	50	Indian Trust (Zuni)	-	-	Salt is mined
210*	Sweazа Lake	S10,T1N,R15W	Largo Creek	96.0	Earth	St. & R	5.0 Av.	20.0	5	Private	-	-	-

* ARIZ: State Dam Safety Jurisdictional Dam NM: On Record with State Engineer

** Uncontrolled Drainage Area

1/ Primary Uses: W-Wildlife, R-Recreation, I-Irrigation, Se-Sediment, St-Stockwater, C-Cooling Pond, F-Flood Control, S-Water Supply, D-Waste Disposal, P-Power, N-Industrial.

2/ ARIZ: Height of Embankment or Depth of Water NM: Water Depth. Embankment Height not shown

3/ Navajo baseline

4/ Capacity at Emergency Spy. Crest

5/ Normal Capacity

6/ Total Drainage Area for water supply; includes area diverted.

7/ Arizona Game and Fish Department has a special use permit with the U.S. Forest Service for these lakes.

8/ The official title of the Silver Creek Irrigation District is the Showlow-Silver Creek Water Conservation & Power District

9/ Forest Service records show Bailey Reservoir under construction as a irrigation reservoir in 1922; cancelled by court order in 1933. The reservoir consists of a normally dry stocktank in 1979.

10/ Some records refer to Carnero Lake as Tyler. Reference No. 12 lists a Tyler Reservoir in NE 1/4, Section 7,T8N,R27E, however, there is no reservoir at this location.

11/ Reference No. 12 states that L.L. Martin Reservoir was abandoned in 1932.

12/ The Westside site is a closed basin. Reference No. 12 (1939) lists this site as an abandoned irrigation reservoir, fed by ditch from the Little Colorado River. There is no storage at this site in 1979.

13/ Colter Res. No. 2 - See Mexican Hay; Colter Res. No. 3 - See Pool Corral; Colter Res. No. 4 - See Hog Wallow

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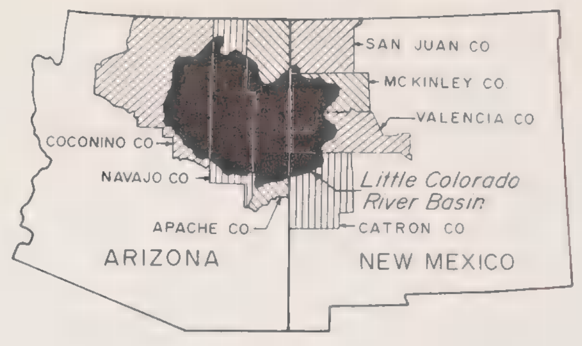

LOCATION MAP

Note: See table for data on reservoirs and lakes

Note:
The boundary as shown for the Hopi Indian Reservation does not reflect division of the joint use area resulting from the Navajo - Hopi Settlement Act of Dec. 22 1974, P. L. 93-531
Final boundaries have not been determined as of this printing

Source:
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series.
Thematic detail compiled by state staff.

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

USDA-SCS-PORTLAND, OR 1981

EXISTING RESERVOIRS AND LAKES

LITTLE COLORADO RIVER BASIN
ARIZONA AND NEW MEXICO

OCTOBER 1979

10 0 10 20 MILES
SCALE 1:1,000,000

M7-EN-23833-4

SECTION 5

SURFACE WATER BUDGETS
(Including Pumped Groundwater)

SECTION 5

SURFACE WATER BUDGETS
(INCLUDING PUMPED GROUNDWATER)

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SURFACE WATER BUDGETS

INTRODUCTION

In the Little Colorado River Basin, where precipitation is low and evaporation is high, water becomes an important concern. Various governmental agencies and private interests have made studies of the Basin's water problems. This paper utilizes and supplements the data developed during the previous investigations.

The Little Colorado River heads in the White Mountains near Greer, Arizona. From Greer it flows north - northwest to confluence with the Colorado River near the east boundary of the Grand Canyon National Park. The river, its forks and tributaries, drain an area of about 26,964 square miles; 21,667 square miles in Arizona and 5,297 square miles in New Mexico.

The tributaries located north and east of the river are characterized by deep, steepsided canyons or washes with their lower reaches having flat, sandy channels with almost vertical side slopes. The tributaries located to the south and west of the river have the steepest slopes; channels are deeply incised and streams flow through deep, narrow canyons for a large part of their length.

The water budgets for the Little Colorado River Basin were compiled at the request of the Arizona Department of Water Resources, and are to be used to update the Arizona State Water Plan. In New Mexico, the State Engineer's Office and the Interstate Stream Commission pursue continuing programs which include making quantitative estimates of water use every five years. The data developed for this study, therefore, will be used by the New Mexico State Agencies in their ongoing studies.

Water budgets were developed for 18 selected water use areas (WUA) in addition to that for the total Basin. In Arizona, the water use areas (with minor modifications) are those defined by the Arizona Department of Water Resources and the U.S. Geological Survey in their studies of ground-water resources for the state. In New Mexico, boundaries for the water use areas follow drainage divides based on boundaries of the Hydrologic Unit Map - 1974 (12).* (See Water Use Areas and Gaging Station Location Map.)

The water budgets for the individual areas and for the total Basin are based on best estimates of water supply, water use and outflow. These are given in both tabular (Table 5-3) and graphical forms (Water Budget Map) for the 1975 stage of water development, but only the tabular form (Tables 5-4, 5-5 and 5-6) was used to display the water budgets under future conditions.

The water budgets developed are not in the truest sense complete water budgets. This results from inadequate data to completely determine the

*Number in parentheses refers to reference listed in back of this section of the appendix.

relationships between surface water and groundwater flow regimes; therefore, net change in water storage (surface and groundwater) cannot be determined. The relationships between surface water and groundwater have been studied in only two locations within the Basin. These are in the southern portions of Navajo and Apache Counties, Arizona.

A groundwater model was developed for the southern part of Navajo County in 1976 and one is presently under development for the southern part of Apache County.

These models were developed by the U.S. Geological Survey at the request of the Arizona Department of Water Resources. Even in these two areas, the models are not adequate to evaluate, in detail, the relationships between the two flow regimes.

The approach used in the study was to define the available water supply as equal to the average annual runoff (including springflow) plus pumped groundwater. The average annual runoff was further divided into two categories--net surface runoff and surface inflow. The net surface runoff is defined as the total runoff within an evaluation unit minus transmission losses; such as channel losses, evaporation, evapotranspiration, etc. Surface inflow is the surface water which enters an evaluation unit from an adjoining water use area (see Surface Water Budget Map).

In this report "water use" is defined in the broad sense and includes all natural and man-controlled demands placed upon the stated water supply. Water use may be further defined with reference to "withdrawal" or "depletion" requirements. "Withdrawal requirement" is defined as the total quantity of water required at the point of diversion to satisfy a given need. "Depletion requirement," on the other hand, is defined as the amount of water removed by a use from the water supply cycle.

Due to the lack of data to adequately determine the depletion requirements, and since the total relationship between surface water and groundwater is not known, withdrawal requirements were used in the water budget analyses. The total amount of water withdrawn for a purpose, therefore, is charged to that purpose.

Surface water outflow is the streamflow leaving an evaluation unit. These are the most reliable values in the water budget tables, since they represent long-term records of streamflow measurements made at several sites.

With the stated definitions, water supply, use and surface water outflows are shown in the water budget tables. (Tables 5-3, 5-4, 5-5 and 5-6.) Other basic assumptions or definitions made with reference to the water budgets are as follows:

1. All surface water flows in the Little Colorado River Channel, from Holbrook to the Basin's outlet, were divided between adjoining water use areas based on the origin of the surface runoff; i.e., flows which originate to the south and west of the river channel are accumulated in the water budgets for the Chevelon, Canyon Diablo and San Francisco Peaks Water Use Areas. Flows which originate to the north and east of the river

channel are shown in the surface water supplies for the Hopi and Bodaway Mesa Water Use Areas. Spring flows discharging directly into the river channel (such as Blue Spring) were divided equally between the adjoining water use areas.

The equal division of spring flows was used since it was not possible, with present data, to determine which side of the river the spring flows originated. The selected division of surface runoff on the other hand was used to indicate the relative magnitude of surface runoff from the north and south sides of the river. The accumulated surface flows at selected points along the river, under 1975 conditions, are shown on the Surface Water Budget Map.

2. Evaporation from individual reservoirs is charged against the major purpose for which the reservoir(s) was constructed; e.g., irrigation, recreation, fish and wildlife, etc. This is true although the reservoirs may be used for more than one purpose. Exceptions to this general rule are noted in the report.

3. Water used by riparian vegetation is included under the fish and wildlife category of the water budget tables.

4. The only channel losses shown in the water budget tables are those occurring along the Little Colorado River between Holbrook and Cameron; i.e., between gaging stations 3970 and 4020. These are the unaccounted for differences in streamflow measurements. There are other channel losses occurring in the river basin, but these losses could not be positively identified. They have been accounted for, however, to some extent, by adjusting the "Net Surface Runoff" values shown in the water budget tables.

It is recognized that this approach has limitations. Some of these include: (1) inadequate number and length of gaging station records for estimating streamflow; (2) erratic nature of streamflow within the Basin from year to year and within the year; (3) the indeterminate effect of transmission losses on streamflow; (4) inadequate data with respect to spring flows and/or groundwater pumpage; (5) limited data for estimating surface or groundwater in storage; (6) inadequate data for estimating evaporation losses, etc. These limitations will be discussed in greater detail in the respective surface water and groundwater sections which follow.

SURFACE WATER

Surface water consists of both streamflow and surface storage. Streamflow is that part of precipitation that appears in streams. Surface storage is water that is impounded on the surface in manmade reservoirs or water that is naturally detained in a drainage basin.

Surface water storage is limited in the Little Colorado River Basin. The total storage capacity within the Basin is estimated to be 276,600 acre-feet (Table 5-1). The amount of water stored during an average year is

TABLE 5-1: ESTIMATED RESERVOIR STORAGE 1/

LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO

WATER USE AREA	AVAILABLE 2/ STOR. CAP. (AC/FT)	ESTI. AVG. ANN. STOR. (AC/FT)
ARIZONA		
(BLM) BLACK MESA	1,900	1,100
(BOD) BODAWAY MESA	100	50
(CDI) CANYON DIABLO	39,200	10,200
(CHV) CHEVELON	34,800	26,900
(CHN) CHINLE	4,400	1,300
(CON) CONCHO	2,900	2,500
(HOL) HOLBROOK	21,300	2,100
(HOP) HOPI	1,600	800
(KAI) KAIBITO PLATEAU	200	100
(PRZ) PUERCO-ZUNI	1,200	600
(SFP) SAN FRANCISCO PEAKS	28,000	9,200
(STJ) ST. JOHNS	37,200	17,900
(SNO) SNOWFLAKE	18,200	6,700
(TUB) TUBA CITY	500	400
(WHM) WHITE MTNS.	31,400	26,500
TOTAL ARIZONA	222,900	106,350
NEW MEXICO		
(CAR) CARRIZO WASH	7,200	5,000
(UPR) UPPER PUERCO	27,400	13,600
(ZUN) ZUNI	19,100	14,800
TOTAL NEW MEXICO	53,700	33,400
TOTAL BASIN	276,600	139,750

1/ Includes estimated storage in livestock ponds. All numbers have been rounded to nearest 100 acre-feet, except for the Bodaway Mesa Area where the average annual storage is to the nearest 50 acre-feet.

2/ Available storage to crest of emergency spillway; or in case of closed basins, it is equal to average annual yield, or storage to low point in drainage divide, whichever is less.

only about one-half of this volume or 139,750 acre-feet. This latter volume includes an estimated 8,400 acre-feet of water stored in approximately 5,600 stock watering ponds scattered throughout the study area. An additional 118,450 acre-feet of water are stored in some 183 fish and wildlife, recreation, irrigation, municipal and industrial and other multiple use impoundments inventoried during the study. (See Section 4 of this appendix.) The remainder of the surface water storage in the study area (12,900 acre-feet) is found in mine tailing reservoirs and closed, natural basins.

Streamflow in most of the Little Colorado River Basin is typical of that in other arid or semiarid lands where channels are dry for long period of time. The flows are confined generally to the channels, although they frequently inundate the flood plains where the channels are not deeply incised. Most of the streamflow in the Basin is in response to direct runoff from rainfall and/or snowmelt, although groundwater sustains flow in several locations within the Basin. (There are approximately 900 springs within the Basin, varying in size from seeps to about 223 cubic feet per second (cfs) flow at or near Blue Spring.)

Streamflow in all portions of the Basin is extremely variable, and the arithmetic average of annual flows has little meaning with regard to the amount of flow that may be expected each year. Because of this extreme variability, long-term gaging station records are important for water resource planning, management and development.

A few gaging stations have been in operation in the study area for nearly 50 years. Other stations, installed in 1940, are approaching 41 years of record. A listing of selected stations, with their periods of record, is given in Figure 5-1 and their locations shown on "Water Use Area and Gaging Station Map." Other pertinent data for the listed gages are given in Table 5-2.

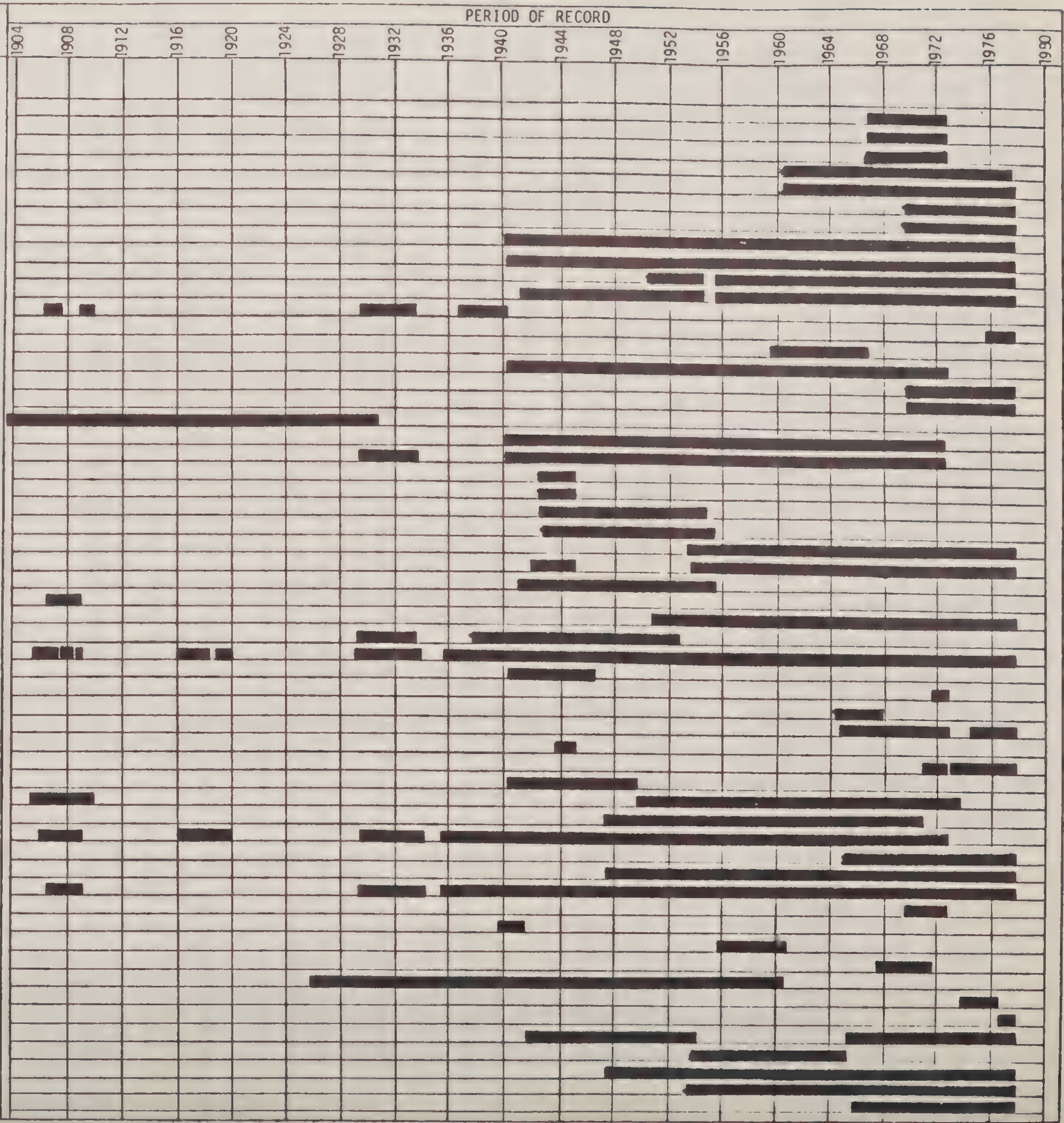
Streamflow data for the period of record for the Little Colorado River at Grand Falls and near Cameron are shown in Figures 5-2 and 5-3. Similar data for the Little Colorado River above Lyman Reservoir and Clear Creek near Winslow are given in Figures 5-4 and 5-5. These graphs illustrate the extreme variability of streamflow in the study area and indicate that planning based on short periods of record can be seriously in error.

Seasonal distribution of the recorded streamflows can be noted from the hydrographs of Figures 5-6, 5-7, 5-8 and 5-9. These hydrographs show the minimum, the median and the maximum monthly flows for each calendar month for the four gaging stations used to illustrate the yearly discharge variability. In the Little Colorado River Basin, the range in flow for most months is from one to more than four orders of magnitude. The lowest median flow generally occurs in June or July and except where spring flow is a factor, the minimum monthly flow for most months is equal to or approaches zero.

In New Mexico, the Little Colorado River Basin includes three principal stream systems: The Puerco River, the Zuni River and Carrizo Wash. The meager streamflow data on these streams indicate that streams with substantial

FIGURE 5-1: BAR CHART OF GAGING STATION RECORDS
LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO

GAGING STATION (Number)	(Location)	DRAINAGE AREA (Mi^2)
LITTLE COLORADO RIVER BASIN		
3832.0	Lee Valley Cr. ab Lee Valley Res. nr Greer, AZ	1.3
3832.2	Lee Valley Trib. nr Greer, AZ	0.5
3832.5	Lee Valley Cr. bl Lee Valley Res. nr Greer, AZ	1.9
3833.0	Filler Ditch at Greer, AZ	-
3834.0	Little Colorado R. at Greer, AZ	30.9
3835.0	Nutrioso Cr. ab Nelson Res. nr Springerville, AZ	83.4
3835.5	Nutrioso Cr. bl Nelson Res. nr Springerville, AZ	86.8
3840.0	Little Colorado R. ab Lyman Res. nr St. Johns, AZ	747
3845.0	Lyman Res. nr St. Johns, AZ	790
3850.0	Lyman Canal Blvd. Lyman Res. nr St. Johns, AZ	-
3855.0	Little Colorado R. bl Lyman Res. nr St. Johns, AZ	790
3860.0	Little Colorado R. at St. Johns, AZ	940
3860.3	Little Colorado R. ab Zion Res. nr St. Johns, AZ	975
3860.5	Largo Cr. nr Mangas, NM	63
3865.0	Little Colorado R. ab Zuni R. nr Hunt, AZ	3,680
3869.0	Rio Nutria nr Ramah, NM	71.4
3869.5	Zuni River ab Black Rock Res. NM	810
3870.0	Zuni River at Black Rock, NM	810
3879.8	Zuni River at Mouth nr Hunt, AZ	2,580
3880.0	Little Colorado R. nr Hunt, AZ	6,280
3885.0	Silver Cr. at Powerplant nr Shumway, AZ	85
3890.0	Rocky Arroyo nr Shumway, AZ	79
3895.0	Daggs Res. and Mexican Lk. nr Shumway, AZ	170
3900.0	Silver Cr. nr Shumway, AZ	172
3905.4	Show Low Cr. nr Lakeside, AZ	68.6
3920.0	Show Low Cr. bl Jaques Dam nr Show Low, AZ	73.0
3925.0	Show Low Cr. at Show Low, AZ	87
3930.0	Silver Creek at Snowflake, AZ	452
3935.0	Silver Creek nr Snowflake, AZ	886
3940.0	Silver Creek nr Woodruff, AZ	942
3945.0	Little Colorado R. at Woodruff, AZ	8,100
3955.0	Puerco River at Gallup, NM	558
3956.5	Puerco River nr Lupton, AZ	1,050
3957.0	Whitewater Arroyo nr Cheechilgeetho, NM	78.5
3959.0	Black Creek nr Lupton, AZ	500
3960.0	Black Creek nr Houck, AZ	648
3961.0	Puerco River nr Chambers, AZ	2,160
3965.0	Puerco River nr Adamana, AZ	2,760
3970.0	Little Colorado R. at Holbrook, AZ	11,300
3975.0	Chevelon Creek bl Wildcat Canyon nr Winslow, AZ	275
3980.0	Chevelon Creek nr Winslow, AZ	794
3983.0	Blue Ridge Res. nr Pine, AZ	71.1
3985.0	Clear Cr. bl Willow Cr. nr Winslow, AZ	321
3990.0	Clear Cr. nr Winslow, AZ	607
3994.0	Jacks Canyon nr Winslow, AZ	280
3995.0	Salt Creek nr Winslow, AZ	287
4006.0	Rio de Flag at Flagstaff, AZ	50.4
4008.5	Upper Lake Mary nr Flagstaff, AZ	53.5
4010.0	Little Colorado R. at Grand Falls, AZ	21,200
4012.5	Moenkopi Wash nr Moenkopi, AZ	1,650
4012.6	Moenkopi Wash at Moenkopi, AZ	1,660
4014.0	Moenkopi Wash nr Tuba City, AZ	2,500
4015.0	Moenkopi Wash nr Cameron, AZ	2,700
4020.0	Little Colorado R. nr Cameron, AZ	26,500
4950.0	Forestdale Cr. Div. from Show Low Cr. nr Show Low, AZ	-
5075.8	East Verde R. Div. from E. Clear Cr. nr Pine, AZ	-



LEGEND

ARIZONA

BLM	Black Mesa Area
BOD	Bodaway Mesa Area
CDI	Canyon Diablo Area
CHV	Chevelon Area
CHN	Chinle Valley Area
CON	Concho Area
HOL	Holbrook Area
HOP	Hopi Area
KAI	Kaibito Plateau Area
PRZ	Puerco - Zuni Area
STJ	St. Johns Area
SFP	San Francisco Peaks Area
SNO	Snowflake Area
TUB	Tuba City Area
WHM	White Mountain Area
	NEW MEXICO
CAR	Carrizo Wash Area
UPR	Upper Puerco Area
ZUN	Zuni Area
• 3965.0	Gaging Station

NOTE:
In Arizona, Water Use Areas are Ground Water Study Areas; in Mew Mexico they represent Hydrologic Boundaries.

BY
ARIZONA WATER COMMISSION
NEW MEXICO STATE ENGINEER
AND
U.S. DEPARTMENT OF AGRICULTURE

WATER USE AREAS AND GAGING STATION LOCATION

LITTLE COLORADO RIVER BASIN

ARIZONA AND NEW MEXICO

JANUARY 1980

10 0 10 20 30 40 MILES

SCALE 1:2,000,000

Source:
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series.
Thematic detail compiled by state staff.

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE USDA-SCS-PORTLAND 1980

M7-OL-24030-16

TABLE 5-2: SUMMARY OF STREAMFLOW DATA FOR SELECTED GAGING STATIONS, LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO

STA [1/] NO.	LOCATION	DRAINAGE AREA (SQ. MI.)	PERIOD OF RECORD (CAL. YRS)	STREAMFLOW AVERAGE (CFS)	STREAMFLOW AVERAGE (AC-FT)	STREAMFLOW MAXIMUM (CFS)	STREAMFLOW MINIMUM (CFS)	UNIT RUNOFF [3/] (INCHES)
3832	Lee Valley Cr. above Lee Valley Res. near Greer, AZ	1.3	1966-72	0.538	390	8	0.02	5.63
3832.2	Lee Valley Trib. near Greer, AZ	0.5	1966-72	0.107	77	5	0	2.89
3832.5	Lee Valley Cr. below Lee Valley Res. near Greer, AZ	1.9	1966-72	0.253	183	6.2	0.03	1.81
3833	Filler Ditch at Greer, AZ	--	1960-77	2.32	1,680	19	0	--
3834	Little Colorado River at Greer, AZ	30.9	1960-77	1.50	10,870	615	0.8	6.60
3835	Nutrioso Cr. above Nelson Res. near Springerville, AZ	83.4	1967-77	5.46	3,960	439	0	0.89
3835.5	Nutrioso Cr. below Nelson Res. near Springerville, AZ	86.8	1967-77	5.12	3,710	465	0	0.80
3840	Little Colorado R. above Lyman Res. near St. Johns, AZ	747	1940-77	20.8	15,070	16,000	0	0.38
3845	Lyman Res. near St. Johns, AZ	790	1940-47 1948-77	Res. capacity at spillway crest-30,600 AC-FT (1953 surveys). (Maximum contents 32,200 AC-FT May 6, 1973.)				
3850	Lyman Canal below Lyman Res. near St. Johns, AZ	--	1950-54 1955-77	11.6	8,400	74	0	--
3855	Little Colorado River below Lyman Res. near St. Johns, AZ	790	1941-54 1955-77	3.22	2,330	603	0	0.06
3860	Little Colorado River at St. Johns, AZ	940	1906-07, 1909, 1929-33 1936-40	7.52	5,440	2,100	0	0.11
3860.3	Little Colorado River above Zion Res. near St. Johns, AZ	975	1975-77	--	--	92	0.09	--
3860.5	Largo Cr. near Mangas, NM	63	1959-66	1.08	785	258	0.02	0.23
3865	Little Colorado River above Zuni near Hunt, AZ	3,680	1940-72	5.16	3,740	552	0	0.02
3869	Rio Nutria near Ramah, NM	71.4	1969-77	4.02	2,913	782	0.01	0.77
3869.5	Zuni River above Black Rock Res. NM	810	1969-77	9.25	6,700	5,200	0	0.16
3870	Zuni River at Black Rock, NM	810	1903-30	27.49	19,900	--	0	0.46

TABLE 5-2: (continued) SUMMARY OF STREAMFLOW DATA FOR SELECTED GAGING STATIONS, LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO

STA [1] NO.	LOCATION	DRAINAGE AREA (SQ. MI.)	PERIOD OF RECORD (CAL. YRS)	STREAMFLOW AVERAGE (CFS)	STREAMFLOW AVERAGE (AC-FT)	STREAMFLOW MAXIMUM (CFS)	STREAMFLOW MINIMUM (CFS)	UNIT [3] RUNOFF (INCHES)
3879.8[2]	Zuni River at mouth near Hunt, AZ	2,580	1940-72	9.2	6,690	3,610	0	0.05
3880	Little Colorado River near Hunt, AZ	6,280	1929-33 1940-72	14.4	10,430	8,000	0	0.03
3885	Silver Cr. at Power Plant near Shumway, AZ	85	1942-45	--	--	--	--	--
3890	Rocky Arroyo near Shumway, AZ	79	1942-45	--	--	--	0.1	--
3895	Daggs Res. and Mexican Lake near Shumway, AZ	170	1942-54	--	--	--	--	--
3900	Silver Cr. near Shumway, AZ	172	1942-55	11.5	8,330	174	0.2	0.91
3905	Show Low Cr. near Lakeside, AZ	68.6	1953-77	10.8	7,820	5,450	0	2.14
3920	Show Low Cr. below Jaques Dam near Show Low AZ	73	1941-45 1953-77	5.83	4,220	2,500	0	1.08
3925	Show Low Cr. at Show Low, AZ	87	1941-55	10.1	7,310	6,250	0	1.58
3930	Silver Cr. at Snowflake, AZ	452	1906-08	--	--	--	0	--
3935	Silver Cr. near Snowflake, AZ	886	1950-77	16.4	11,880	10,100	0	0.25
3940	Silver Creek near Woodruff, AZ	942	1929-33 1935-52	25.5	18,460	11,000	0	0.37
3945	Little Colorado River at Woodruff, AZ	8,100	1905-08 1915-19 1929-33 1935-77	51.1	37,020	25,000	0	0.09
3955	Puerco River at Gallup, NM	558	1940-46	8.57	6,200	3,700	0	0.21
3956.5	Puerco River near Lupton, AZ	1,050	1971-72	--	--	20,900	0	--
3957	Whitewater Arroyo near Cheechilgeetho, NM	78.5	1964-67	--	--	2,480	0	--
3959	Black Creek near Lupton, AZ	500	1964-72 1974-77	7.70	5,580	7,160	0	0.21
3960	Black Creek near Houck, AZ	648	1943-45	--	--	1,380	0	--
3961	Puerco River near Chambers, AZ	2,160	1970-72 1973-77	--	--	17,800	0	--
3965	Puerco River near Adamana, AZ	2,760	1940-49	64.2	46,480	30,000	0	0.32
3970	Little Colorado River at Holbrook,	11,300	1905-09 1949-73	134	97,080	24,200	0	0.16

TABLE 5-2: (continued) SUMMARY OF STREAMFLOW DATA FOR SELECTED GAGING STATIONS, LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO

STA 1/ NO.	LOCATION	DRAINAGE AREA (SQ. MI.)	PERIOD OF RECORD (CAL. YRS.)	STREAMFLOW AVERAGE (CFS)	STREAMFLOW AVERAGE (AC-FT)	STREAMFLOW MAXIMUM (CFS)	STREAMFLOW MINIMUM (CFS)	UNIT 3/ RUNOFF (INCHES)
3975	Chevelon Cr. below Wildcat Canyon near Winslow, AZ	275	1947-70	49.5	35,860	19,800	0	2.44
3980	Chevelon Cr. near Winslow, AZ	794	1905-08 1915-19 1929-34 1935-72	50.3	36,440	25,300	1.0	0.86
3983	Blue Ridge Res. near Pine, AZ	71.1	1964-77	Total capacity 19,500 AC-FT (Max. storage 16,000 AC-FT, Dec 30, 1965)				--
3985	Clear Cr. below Willow Cr. near Winslow, AZ	321	1947-77	75.9	54,990	16,400	0	3.21
3990	Clear Cr. near Winslow, AZ	607	1906-09 1929-34 1935-77	75.7	54,840	50,000	0	1.70
3994	Jacks Canyon near Winslow, AZ	280	1969-72	--	--	1,970	0	--
3995	Salt Creek near Winslow, AZ	287	1939-41	--	--	2,900	0	--
4000	Little Colorado River near Winslow	16,100	1954-56	(Discharge below 100 cfs only)				
4006	Rio de Flag at Flagstaff, AZ	50.4	1955-60	--	--	56	0	--
4008.5	Upper Lake Mary near Flagstaff, AZ	53.5	1967-71	Usable capacity 15,620 AC-FT (1967 survey) Maximum storage 16,100 AC-FT March 30, 1969				
4010	Little Colorado River at Grand Falls, AZ	21,200	1925-60	253	183,200	50,500	0	0.16
4012.5	Moenkopi Wash near Moenkopi, AZ	1,650	1973-76	--	--	2,380	0	--
4012.6	Moenkopi Wash at Moenkopi, AZ	1,660	1976-77	--	--	5,420	0	--
4014	Moenkopi Wash near Tuba City, AZ	2,500	1941-53 1965-77	15.2	11,010	12,100	0	0.08
4015	Moenkopi Wash near Cameron, AZ	2,700	1953-65	13.8	9,990	8,380	0	0.07
4020	Little Colorado River near Cameron, AZ	26,500	1947-77	219	158,700	24,900	0	0.11
4950	Forestdale Cr. Div. from Show Low Cr. near Show Low, AZ	--	1953-77	4.56	3,300	--	0	--
5075.8	East Verde R. Div. from Clear Cr. near Pine, AZ	--	1965-77	15.5	10,900	--	0	--

1/ Station numbers are those used in publication of surface-water records, except prefix 9 is omitted. Water Use Areas and Gaging Station Location Map shows location of gaging stations.

2/ Data for gage No. 3879.8 is based on difference in data between gages 3865 and 3880.

3/ The term Unit Runoff as shown in this table is the annual volume of water past the gage per square mile of drainage area expressed in inches of runoff from the total drainage area. The values as shown are net values; they account for upstream storage and use.

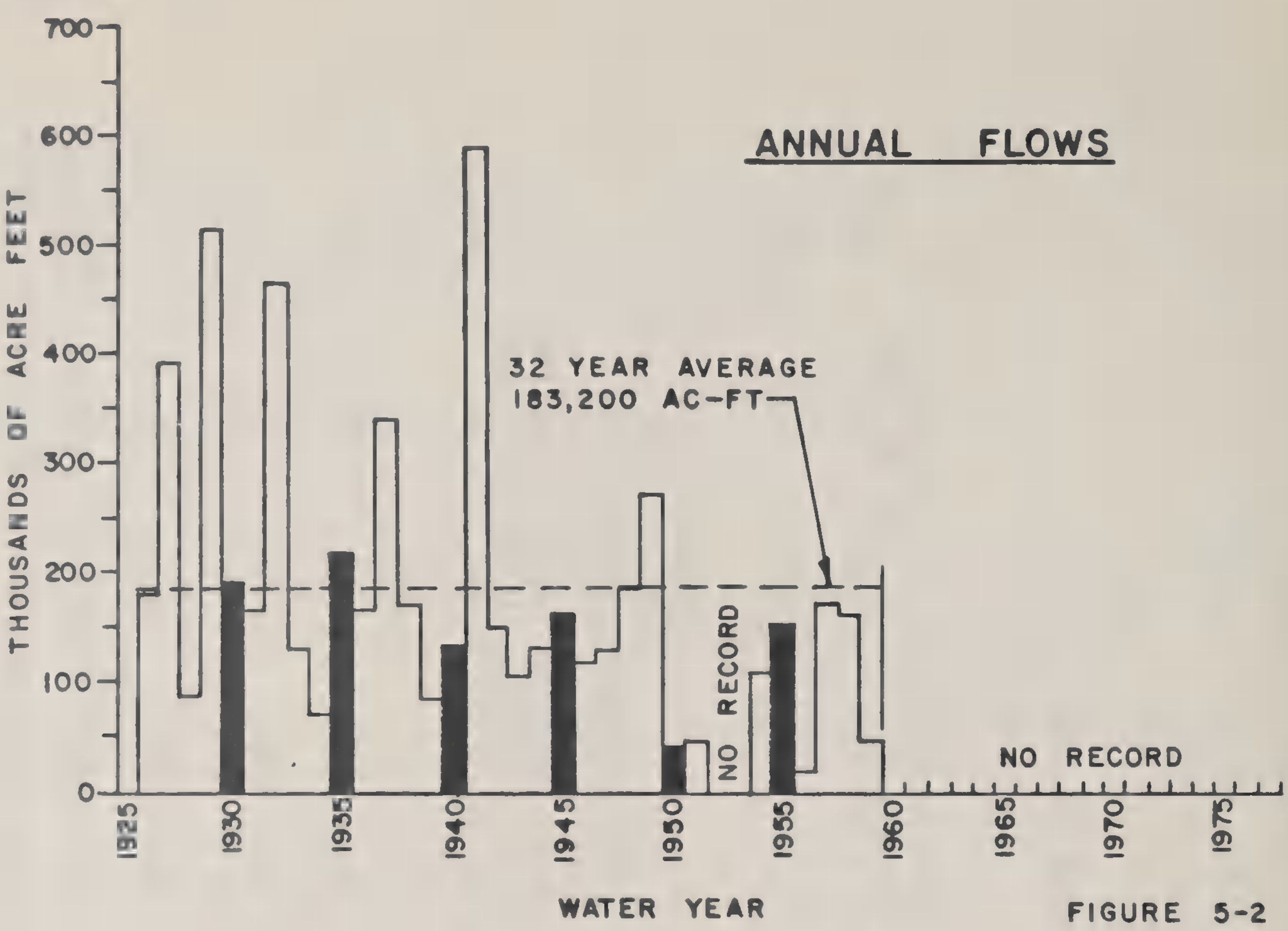
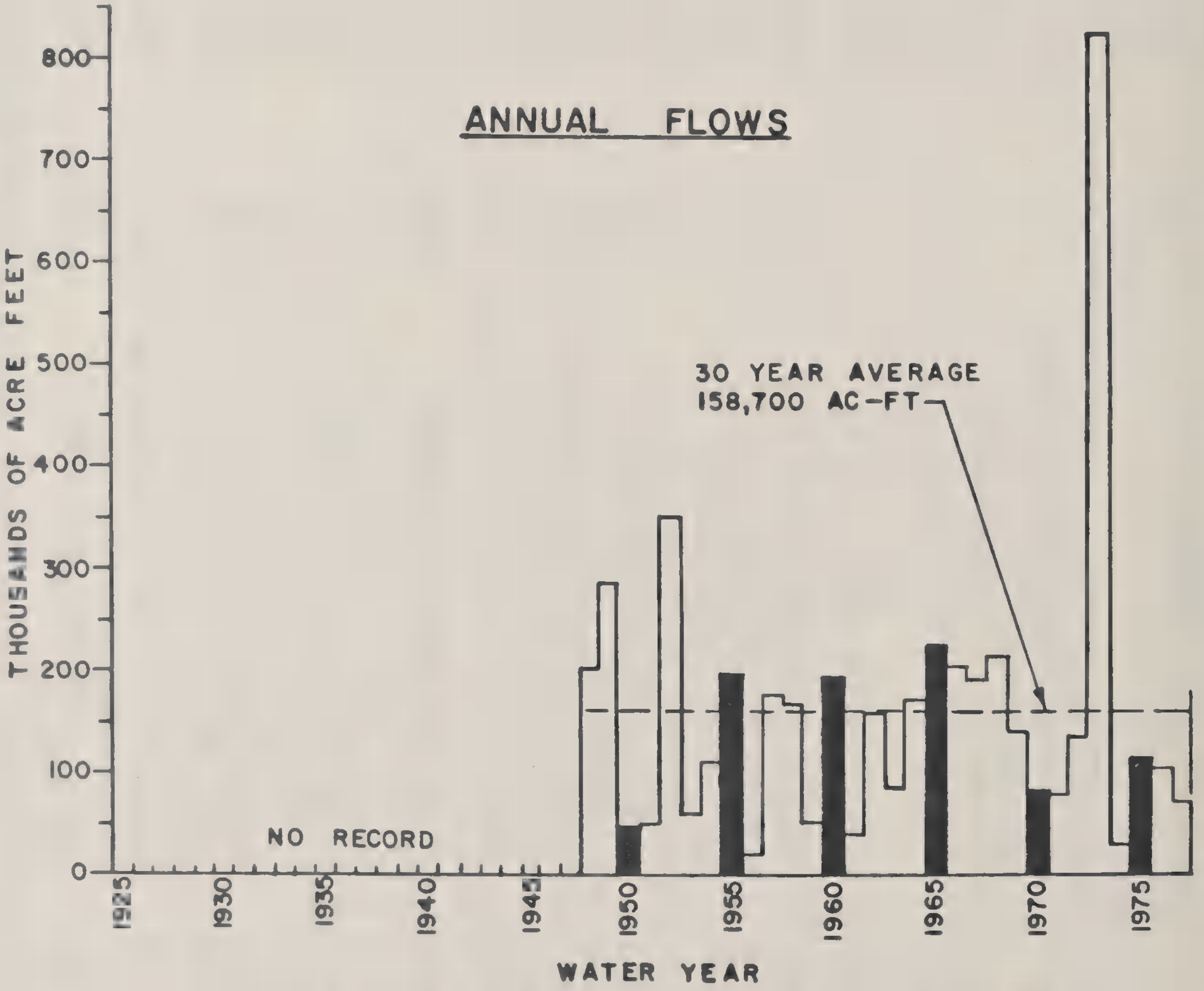


FIGURE 5-2

LITTLE COLORADO RIVER AT GRAND FALLS*



LITTLE COLORADO RIVER NR. CAMERON*

*Solid bar lines on 5 year intervals used for illustration only.

Source U.S. Geological Survey

FIGURE 5-3

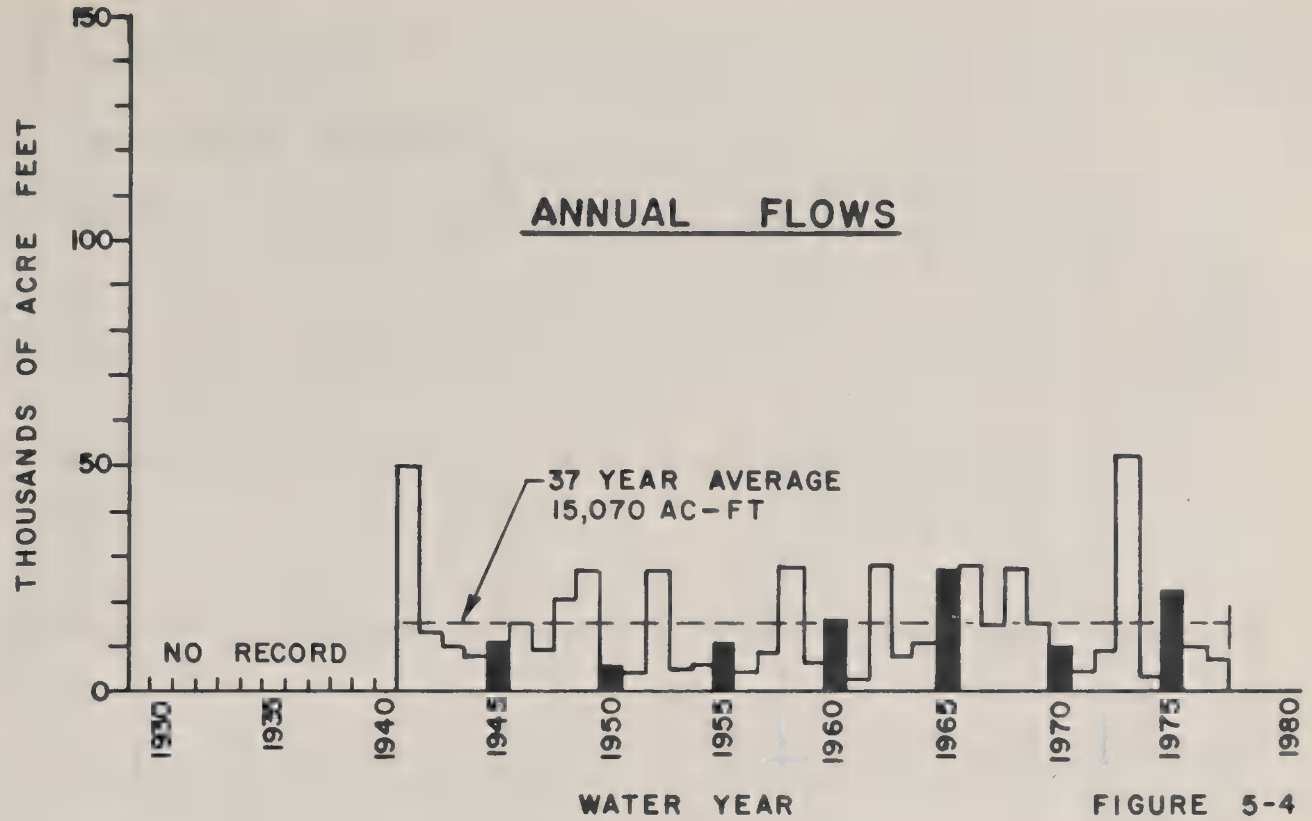
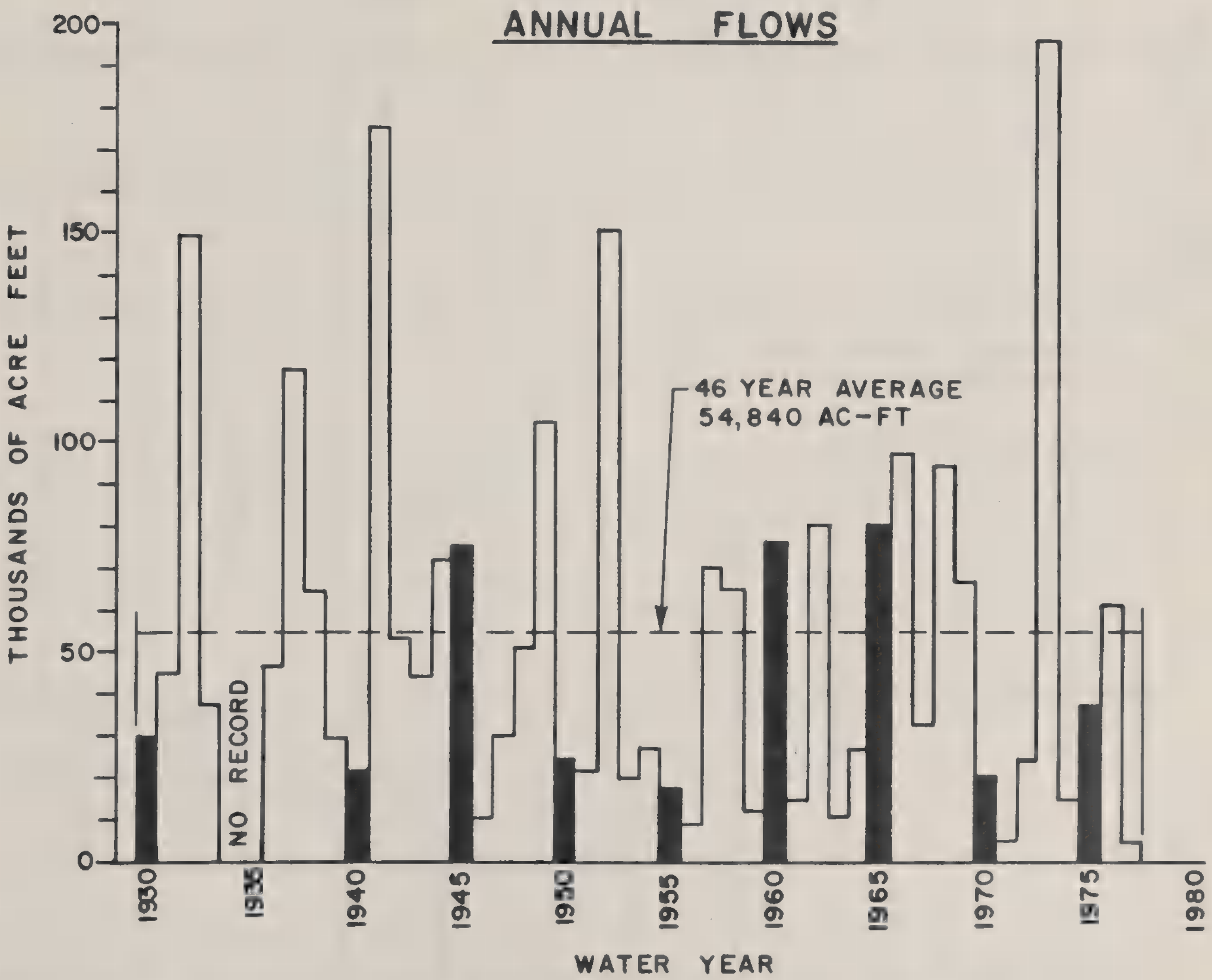


FIGURE 5-4

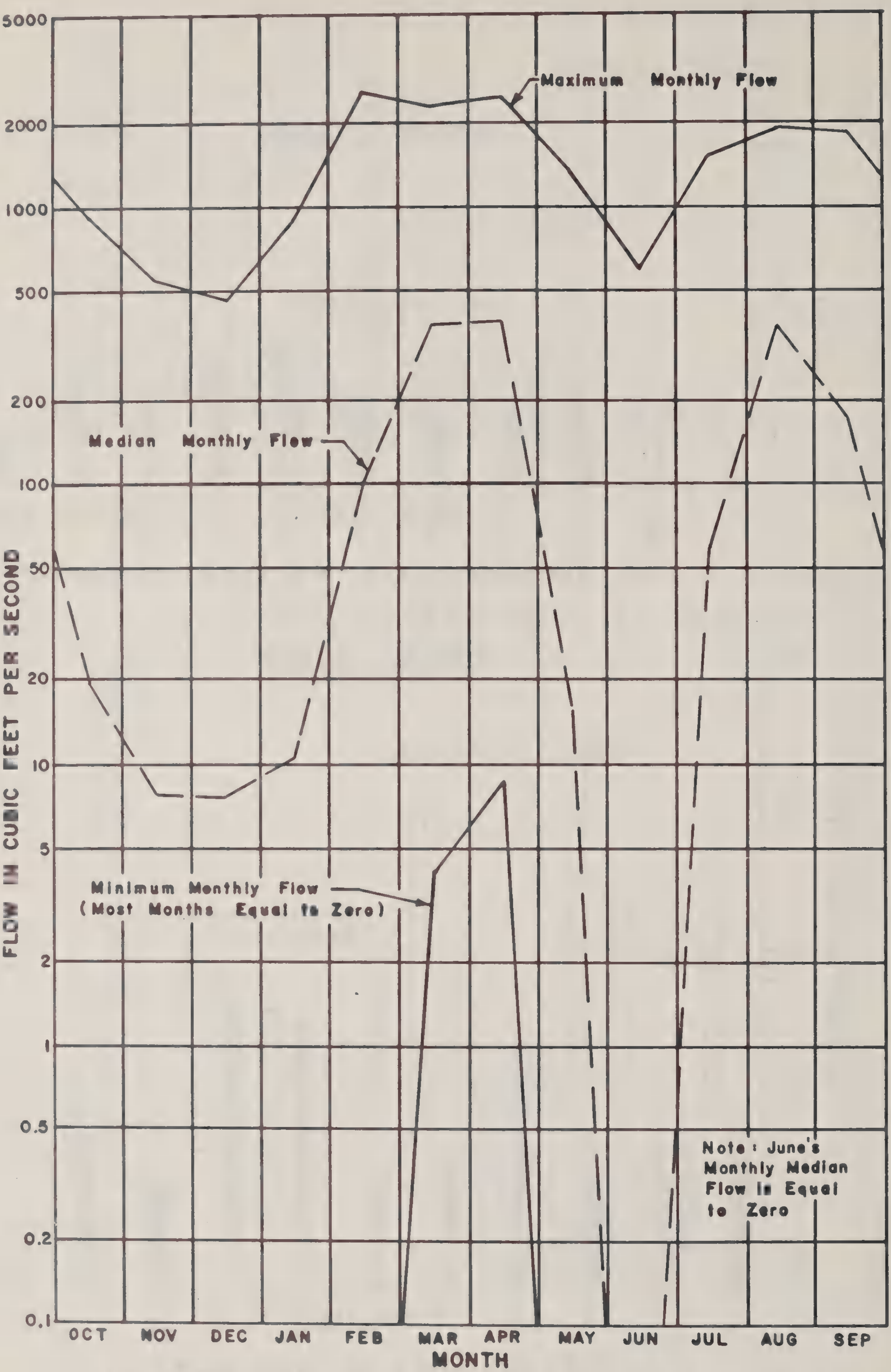
LITTLE COLORADO RIVER AB. LYMAN RESERVOIR*



CLEAR CREEK NR. WINSLOW*

FIGURE 5-5

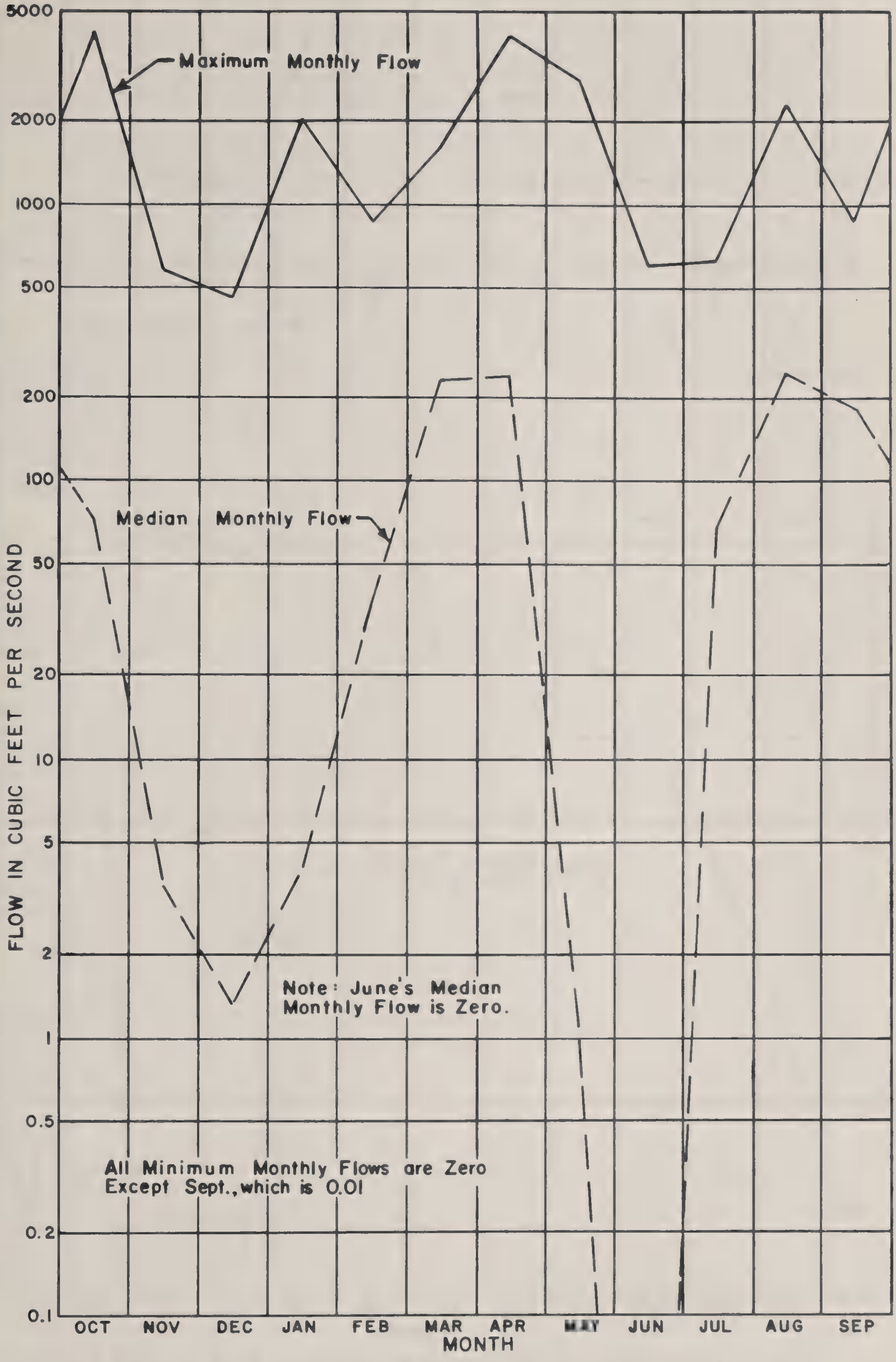
*Solid bar lines on 5 year intervals used for illustration only.
Source: U.S. Geological Survey



MAXIMUM, MEDIAN AND MINIMUM MONTHLY FLOWS LITTLE COLORADO RIVER, AT GRAND FALLS FOR PERIOD 1926-51, 1954-59

SOURCE: U.S. GEOLOGICAL SURVEY

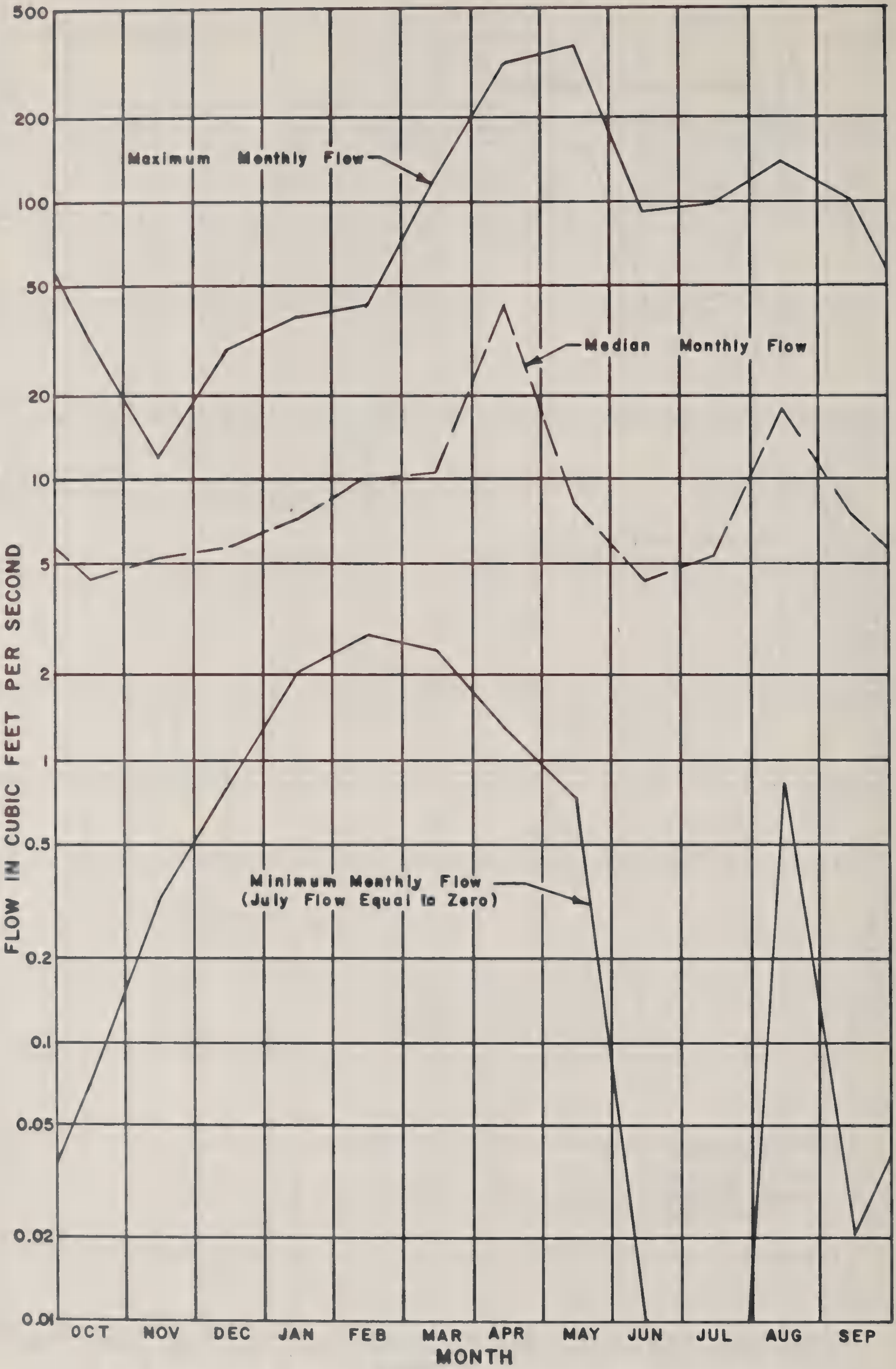
FIGURE 5-6



MAXIMUM, MEDIAN AND MINIMUM MONTHLY FLOWS LITTLE COLORADO RIVER NR. CAMERON FOR PERIOD 1948—1975

Source: U.S. Geological Survey

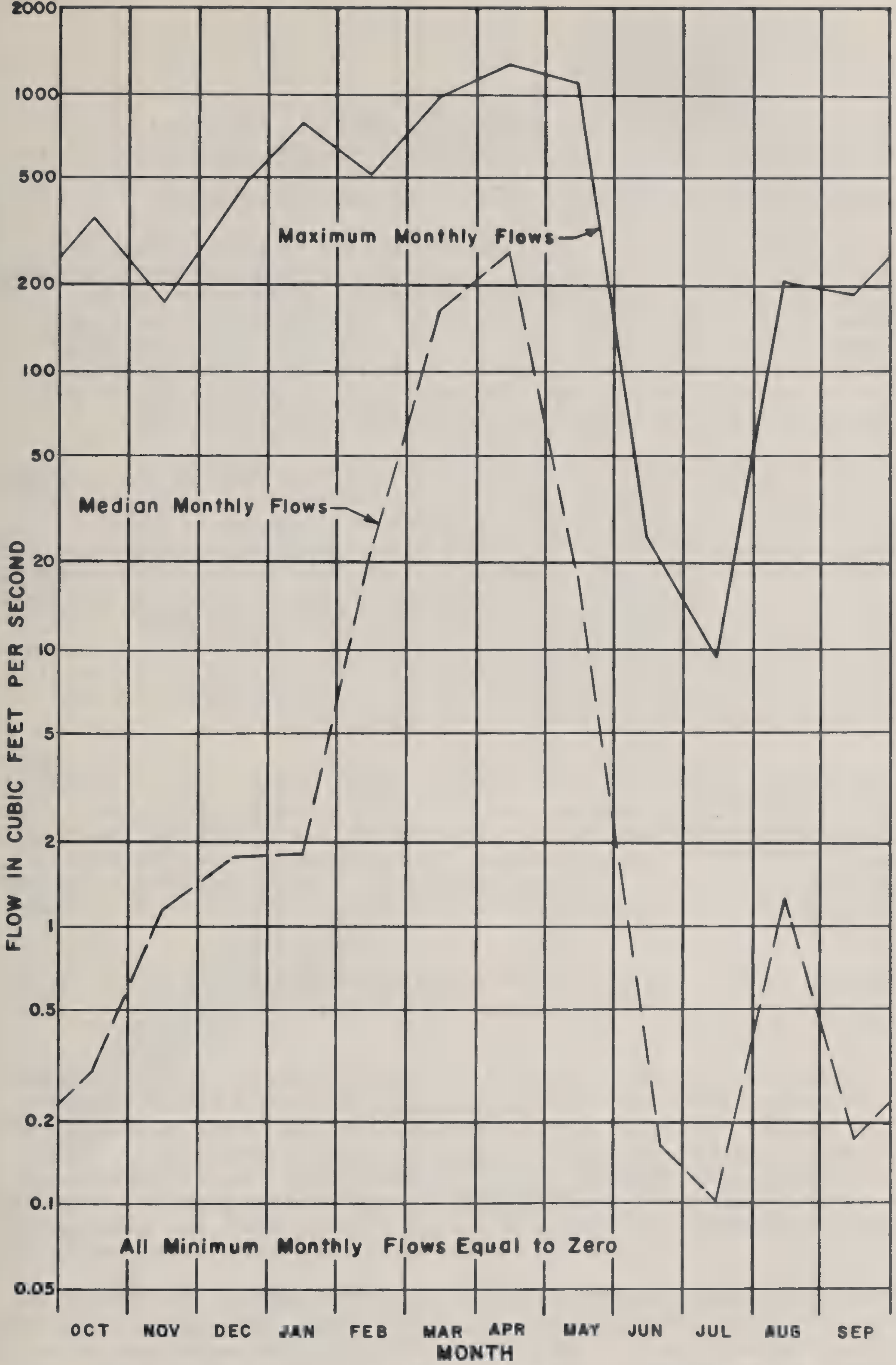
FIGURE 5-7



MAXIMUM, MEDIAN AND MINIMUM MONTHLY FLOWS LITTLE COLORADO RIVER, ABOVE LYMAN RESERVOIR FOR PERIOD 1941-75

SOURCE: U.S. GEOLOGICAL SURVEY

FIGURE 5-8



MAXIMUM, MEDIAN AND MINIMUM MONTHLY FLOWS CLEAR CREEK NEAR WINSLOW FOR PERIOD 1930-33, 1936-75

SOURCE: U.S. GEOLOGICAL SURVEY

FIGURE 5-9

headwater drainage area in the mountains show at least a small amount of base flow, if measured near the headwaters, but the streams become more intermittent in a downstream direction. Most streams are ephemeral or have only small intermittent flows at the lower elevations.

Four stream flow records (continuous recording) were examined in the New Mexico portion of the Basin. Their short periods of record, ranging from five to eight years, make any predictions using these records unreliable. Average monthly flows were highest in March or April for three of the gages and in August for the other gage. The March-April highs show the influence of snowmelt while the August high is probably due to thunderstorm activity. Comparing annual flows to the average annual flow shows the annual stream flows to be quite variable.

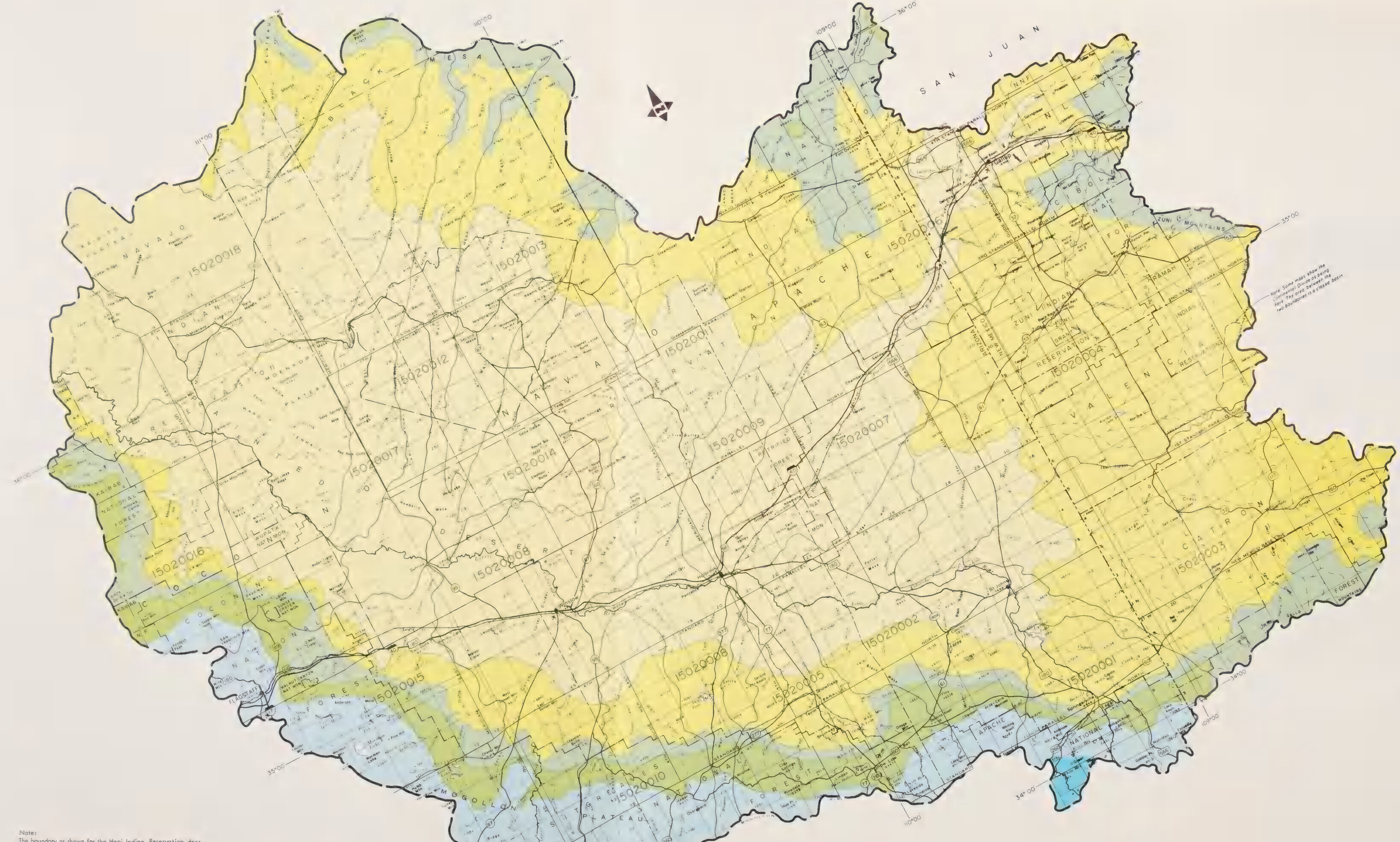
The Average Annual Unit Runoff map, which follows, shows the distribution of unit runoff in the study area. The total flow from a drainage basin, as measured at a gaging station, is expressed on the map in terms of average depth of yearly runoff in inches over the Basin. The map graphiclly illustates that runoff is geatest in the mountains and lowest in the valley regions. This results from the topography and higher amounts of precipitation over the mountains (in the form of both rainfall and snow). Where stream channels leave the mountains and enter alluvial valleys, the unit runoff of a stream tends to decrease in a downstream direction. This is due to less precipitation, high transpiration and infiltration losses and high evaporation rates at the lower elevations.

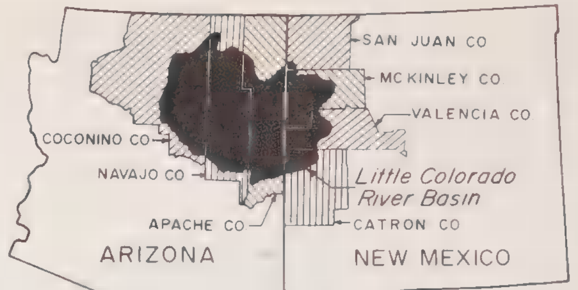
The present study is not of sufficient detail to model the variability of the streamflows as they flow from the mountains downstream to their watershed outlet(s). An attempt was made, however, to quantify the amount of water available at selected points along a stream's course and within selected study areas. This was done through a study of streamflow records for gaged areas and estimates of average annual flows for ungaged areas based on the Unit Runoff Map.

Average annual flows were chosen as the study parameter to smooth out the extreme variability of annual runoff and to help quantify the total amount of water available at any location.

Figure 5-1 and the Water Use Areas and Gaging Station Location Map show that surface water records are both sparse and erratic within the Basin. The longest, continuous period of record is on the Little Colorado River at Woodruff. This record runs from April 1929 to the current year, except for the period of December 1933 to September 1935. Short, intermittent periods of record are also available at this location from 1905 thru 1919. Similar periods of records are available on Clear Creek and Chevelon Creek near Winslow, except that the Chevelon Creek gage was discontinued in 1972.

Through correlation with the Cameron streamflow records, the missing 1933 and 1934 annual flows at Woodruff were estimated. This gave a continuous, 48-year period of record from 1930 to 1977, and this period was used as the "base period" for the study.





LOCATION MAP

AVERAGE ANNUAL UNIT RUNOFF

LITTLE COLORADO RIVER BASIN

ARIZONA AND NEW MEXICO

1979

SCALE 1:1,000,000

BY

ARIZONA WATER COMMISSION

NEW MEXICO STATE ENGINEER

AND

U.S. DEPARTMENT OF AGRICULTURE

Note:
The boundary as shown for the Hopi Indian Reservation does not reflect division of the joint use area resulting from the Navajo-Hopi Settlement Act of Dec. 22, 1974, P. L. 93-531. Final boundaries have not been determined as of this printing.

Source:
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series. Thematic detail compiled by state staffs from previously published SCS data.
U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

USDA SCS PORTLAND, OR 1979

M7-EN-23833-2

Several of the surrounding gages were regressed against the Woodruff gage and/or with each other in order to extend their records. These included two gages on the Little Colorado River near Hunt, and gages at Holbrook, Grand Falls and near Cameron. Tributary streams for which "base period" runoffs were estimated include Silver Creek near Snowflake and near Woodruff, Black Creek near Lupton, Puerco River near Adamana, Chevelon Creek near Winslow, Clear Creek near Winslow and Moenkopi Wash near Cameron.

In addition to regression analysis against the Woodruff gage record, the records on the Little Colorado River at Grand Falls and near Cameron were regressed against each other and against the Clear Creek gage near Winslow. Each of these regressions indicated that the 32-year period of record (1926-51, 1954-59) at Grand Falls represents a relatively wet period of flow, whereas, the 30-year period of record (1948-77) for the gage near Cameron, with the exception of the 1973 water year, was a relatively dry period. This trend is confirmed by comparing Figures 5-2 and 5-3. Figure 5-10, which shows the 30-year Moving Average for the Clear Creek gage near Winslow, also indicates the downward trend in average annual flows for the latter years.

Based on the regression analysis, the estimated "base period" average annual flows at Grand Falls and near Cameron are 167,000 and 179,000 acre-feet, respectively. These compare with recorded average annual flows of 183,200 and 158,700 acre-feet for the respective gages (Table 5-2). The relative magnitudes of the "base period" average annual flows are the reverse of those for the periods of record. These results are further confirmed by comparing concurrent flows for the period 1948-59.

The above descriptions indicate that determining average annual flows from gaged records is not only dependent upon the length of records, but is also affected by the period during which the records were collected.

Using the "base period" flows, the channel losses between Grand Falls and Cameron were estimated at 11,600 acre-feet per year or 230 acre-feet per mile for the 50 mile reach. This water is assumed to be lost to groundwater recharge, transpiration, evaporation or in some other manner not accounted for in the water budget analysis.

Other channel losses were noted on the Little Colorado River between Holbrook and Grand Falls. In this 102-mile reach, there are three gaged areas: Little Colorado River at Holbrook (11,300 sq. mi.); Chevelon Creek near Winslow (794 sq. mi.); and Clear Creek near Winslow (607 sq. mi.). Although the gaged areas include only about 60 percent (12,701 sq. mi.) of the total drainage area above Grand Falls (21,200 sq. mi.), the sum of the three recorded average annual flows exceeds that recorded at Grand Falls (see Table 5-2). When local inflow is added for the ungaged areas (estimated to be 30,900 acre-feet from the Unit Runoff Map), the total estimated flow in this reach exceeds that recorded at Grand Falls by more than 36,000 acre-feet per year. This would indicate a channel loss of approximately 350 acre-feet per mile for the 102-mile reach. Should the "base period" flows be used, which were derived from regression analyses, the total loss between the Holbrook and Grand Falls gages would approach 55,000 acre-feet per year or 540 acre-feet per mile.

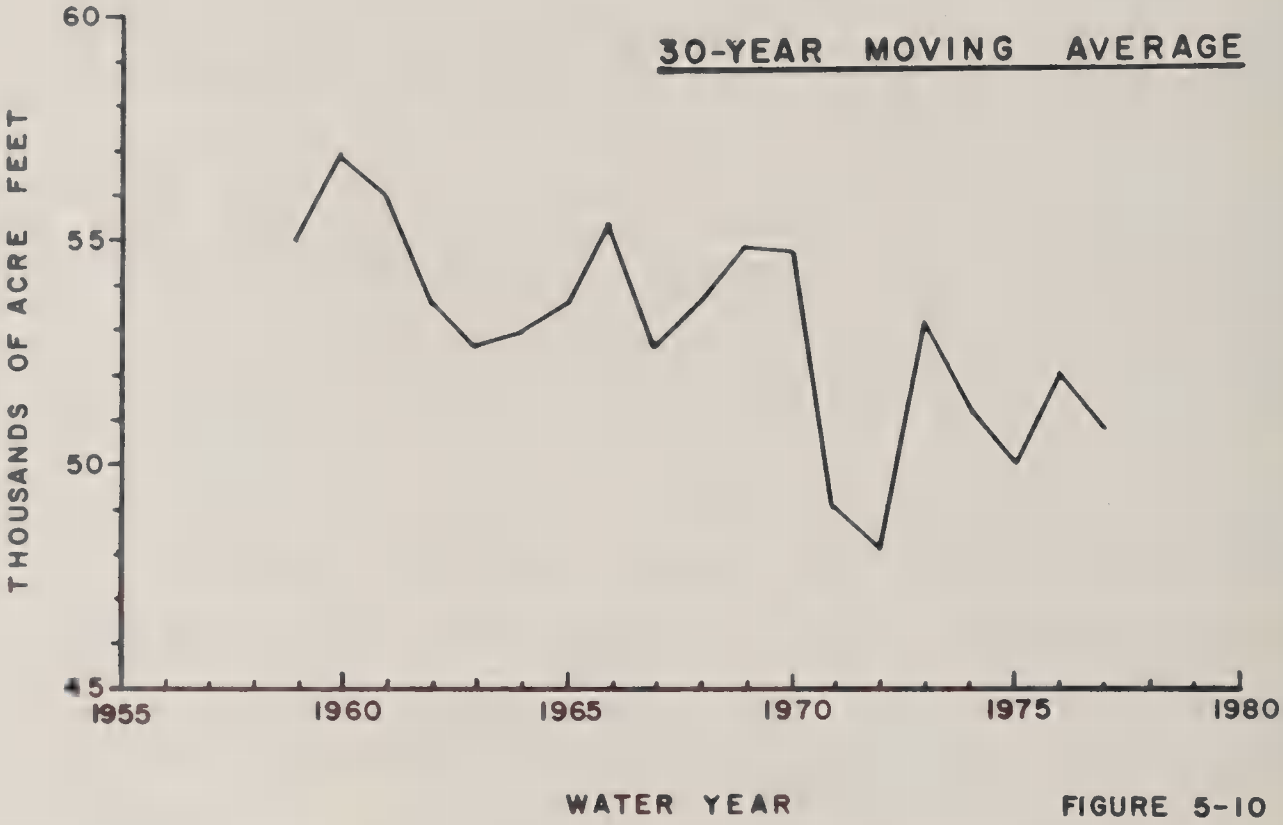


FIGURE 5-10

CLEAR CREEK NR. WINSLOW, AZ.

Another problem, however, was recognized in analyzing the Holbrook record. This gage appears to be overestimating the total volume of flow at Holbrook.

Comparing "base period" flows at Holbrook, Woodruff and Adamana, it would appear that considerable spring flow or groundwater discharge is occuring between these gages. These results, however, are not confirmed by field observations. The observed spring flow in the area is not sufficient to make the "base period" flows balance. Regression analyses show that approximately 24,750 acre-feet per year are needed to adjust the upstream flows to the "base period" flow at Holbrook. This water in turn would need to be lost between Holbrook and Grand Falls.

For this reason, it was decided to estimate the average annual flow at Holbrook using the upstream gaged records plus estimated local inflow. This produced an average annual discharge at Holbrook of about 75,250 acre-feet. The estimated channel loss between Holbrook and Grand Falls, therefore, is reduced to 30,350 acre-feet per year or 300 acre-feet per mile.

Other anomalies discovered during the streamflow analysis occur within the Chevelon and Clear Creek drainage areas. These watersheds are two of the better gaged watersheds in the Basin from the standpoint of the total number of gages located within the watersheds. There are tandem gages located within each watershed. On Clear Creek, the contents of Blue Ridge Reservoir are also gaged.

The Clear Creek gage, located below Willow Creek, and the Chevelon Creek gage located below Wildcat Canyon are near the same elevation, and measure runoff from areas having gneerally the same high runoff producing characteristics (see Table 5-2 and Average Annual Unit Runoff Map). The average annual runoffs measured at these two gages are 54,900 and 35,860 acre-feet, respectively. Their respective drainage areas are 321 and 275 square miles.

The average annual runoff recorded at the two lower gaging stations on these two streams, are 54,840 and 36,440 acre-feet, respectively. These are for drainage areas of 607 square miles on Clear Creek and 794 square miles (excluding 200 square miles of noncontributing area) on Chevelon Creek. Although the drainage areas have more than doubled on Clear Creek, and nearly tripled on Chevelon Creek, there is very little increase in the average annual streamflows. Actually, there is a slight decrease in the recorded streamflow on Clear Creek.

The decrease on Clear Creek is partly explained in that some water is being diverted to Winslow for irrigation upstream of the gage. The Clear Creek gage measures only that portion of the total flow which overtops the diversion dam. The estimated diversion to Winslow, however, is only about 1,760 acre-feet per year. Another cause for the limited runoff volume at the lower gage on Clear Creek is a decrease in the unit runoff. This results from a decrease in precipitation at the lower elevations. (See Annual Precipitation Map.)

On Chevelon Creek, the situation is somewhat different. Black Canyon, a major tributary to Chevelon Creek, heads in the mountains near Heber; and according to the unit runoff map, should have similar runoff characteristics as Chevelon Creek above Wildcat Canyon. However, there is very little evidence of runoff near the mouth of the Canyon. Local residence also have indicated that flow within the Canyon is limited.

A partial explanation for this phenomenon is that several fault lines exist in the area. One of these faults actually crosses perpendicular to the stream channel and several others run parallel to the channel. It was theorized that much of the runoff could be lost in these fault zones. Also, there are several potholes or naturally closed basins in or near the study area. One of the largest sinks in the Little Colorado River Basin, which is Dry Lake, is located just to the east of Chevelon Creek.

Other evidence that water is lost through sinkholes or cavernous limestone conditions in this general area is the Canyon Diablo Watershed. This watershed is located to the west of Clear Creek. Since the construction of the Canyon Diablo Dam near the mouth of the Canyon, there has been little or no flow through the dam's spillways, and yet, there is little water being stored in the structure. This is due to solution channels which have formed in the impoundment area upstream of the dam. Thus, much of the surface runoff in the Black Canyon area could also be lost due to the geologic formations found in the area.

Although the above descriptions may not fully explain the anomalies experienced concerning the flows on Clear and Chevelon Creeks, the average annual flows based on gaged data and adjusted for the "base period", were used in the water budget analyses.

Other areas within the Basin that contribute litte or no runoff to the Little Colorado River channel are shown on a map entitled, "Areas Which Contribute Little or No Streamflow to the Little Colorado River." This map follows and helps to explain the limited runoff in some portions of the Basin. The map was prepared from information developed by the U.S. Geological Survey (14) and from a study of 7 1/2 minute and 15 minute USGS quadrangle maps.

The major use of surface waters in the Basin is for agriculture. This use accounts for over 76 percent of total surface water withdrawals in the Arizona portion of the Basin. This figure includes uses for both irrigation and livestock water supply. Except for spring developments in selected areas, the City of Flagstaff is the only community presently using surface waters for municipal and industrial purposes. Some surface waters are also being evaporated from fish and wildlife, recreation and other reservoirs.

In New Mexico, all agricultural water use is from surface water, except livestock water, which is 50 percent surface water and 50 percent groundwater. Water used by fish and wildlife and for recreation is supplied by surface water. Table, 5-3 and the Water Budget Map show the amounts of surface water that flows out of New Mexico into Arizona.

In most of Arizona and New Mexico, surface waters have been fully appropriated. The Little Colorado River Basin, however, does have some surface water still available for appropriation. Unfortunately, much of this water is not available at points of intensive use. Also, most reservoir construction has been discouraged because of: (1) lack of suitable sites, (2) the considerable sediment storage which must be provided, (3) high evaporation losses from any stored water, and/or (4) water rights problems.

The New Mexico State Engineer may permit new appropriations or changes in surface water rights provided no detrimental effect to existing rights will result. In Arizona, surface water rights are presently being readjudicated.

GROUNDWATER

Groundwater is water that has infiltrated the soil and percolated downward and reached the zone of saturation. Water also occurs underground in unsaturated zones where voids are filled with water and air. This latter water, although it is a part of the groundwater system, is not readily yielded to wells, but is used by plants for their growth, is evaporated, or is retained in the soil by the soil particles.

In the saturated zone, the formations, groups of formations, or parts of formations that contain sufficient permeable materials to yield significant quantities of water to wells and springs are called aquifers (3). In the Little Colorado River Basin, groundwater is obtained from both consolidated sedimentary rocks and from unconsolidated stream-valley alluvium.

The principal types of consolidated sediments include sandstone, siltstone, claystone, shale and limestone. Sandstone and limestone comprise the major aquifers of the Basin. The poorly permeable siltstone, claystone and shale act as confining layers which retard or limit vertical movement of groundwater. For this reason, water may be found under both artesian (confined) and water table (unconfined) conditions within the consolidated rock formations.

The consolidated rock formations have been classified into three major aquifer systems. These are referred to as the C, N and D aquifer systems. The C aquifer system consists principally of the Coconino Sandstone (or its laterally equivalent Glorieta and De Chelly Sandstone) and the Kaibab Limestone of Permian Age and the Shinarump member of the Chinle formation of Triassic Age. The N aquifer system consists of the Dakota Sandstone of Cretaceous Age and the Morrison formation and Cow Springs Sandstone of Jurassic Age.

The C aquifer system (or its individual components) underlies most of the Basin, and is the most important with reference to any water budget study within the Basin. Geologic formations included in this system consist mainly of fine to medium grained sandstone. In some areas it is of low permeability due to cementation. In other areas, it is fractured, thereby resulting in locally high permeability and large well yields. For example, wells in the Holbrook-Joseph City area generally have relatively high yields ranging from 450 to 2,000 gallons per minute (gpm).

Generally speaking, in the southern part of the Basin, groundwater in the C multiple-aquifer system occurs under water table conditions. In this area, the Coconino or the overlying Kaibab limestone lies at or near the surface. Toward the north, the Coconino dips under the younger, relatively impermeable, Moenkopi (Triassic) Formation and water is contained under artesian or confined conditions. In some areas, the artesian pressure is sufficient to cause natural springs or flowing wells, when the wells penetrate the confining layer. Some vertical leakage from the Moenkopi to the alluvium may occur through faults or other fractured zones.

In addition to the Navajo Sandstone, sandy facies of the Kayenta Formation and the Lukachukai Member of the Wingate Sandstone comprise the N aquifer system. These formations consist mainly of crossbedded sandstones with some interbedded mudstone, shale and limestone. Water yield from this system is generally small. Water is discharged from this system along Moenkopi Wash and into the alluvium along Oraibi and Dinnebito Washes.

The main aquifer of the D aquifer system is the Dakota Sandstone. The Cow Springs Sandstone, Westwater Canyon Sandstone Member of the Morrison Formation, and Entrada Sandstone are hydraulically interconnected with the Dakota Sandstone. Groundwater in the system is under artesian pressure. Water yields from this system are generally small. This system is well developed in the Black Mesa Basin.

The volume of groundwater available from the valley alluvium within the Basin is small in comparison to that stored in the consolidated rocks. This is mainly due to the limited volume of such sediments in the Basin. The valley alluvium generally consists of unconsolidated sand, silt, clay and gravel; and when saturated, readily yields water to wells. Groundwater is generally under water table conditions in the alluvium.

The total volume of groundwater stored in a 100-foot thick section in the various aquifers of the Basin has been estimated by the Arizone Department of Water Resources and U.S. Geological Survey to be about 250 million acre-feet.

A general indication of the availability of groundwater from the Basin's aquifers, together with an indication of its quality, is shown on the map(s) entitled "Availability of Groundwater for Irrigation, Municipal and Industrial Use in the Little Colorado River Basin." Maps have been developed which show areas that will yield 25, 75, 200 and 500 gpm from a 100 day pumping level of 2,000 feet or less below land surface. (Note map(s) following this page.) This map(s) can be used as a guide by individuals or community planners to determine the general locations of groundwater for possible development, but it must be recognized that detailed investigations will be needed in order to make sound decisions concerning actual development.

Groundwater is replenished from several sources: (1) infiltration of runoff resulting from precipitation that falls on the rocks exposed in the mountains along the flanks of the Basin; (2) direct penetration of precipitation on the Basin's soils; (3) infiltration of water used for irrigation; and (4) infiltration of channel flows or seepage from manmade reservoirs or naturally closed basins.

LEGEND

~30~ Precipitation (In Inches)

NORMAL ANNUAL PRECIPITATION 1941-1970

LITTLE COLORADO RIVER BASIN

ARIZONA AND NEW MEXICO

APRIL 1981

10 0 10 20 30 40 MILES

SCALE 1:2,000,000

Source:
Laboratory of Climatology Arizona State University.
Climatography of the U.S. (New Mexico).
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series.
Thematic detail compiled by state staff.

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

USDA SCS PORTLAND OR 1981

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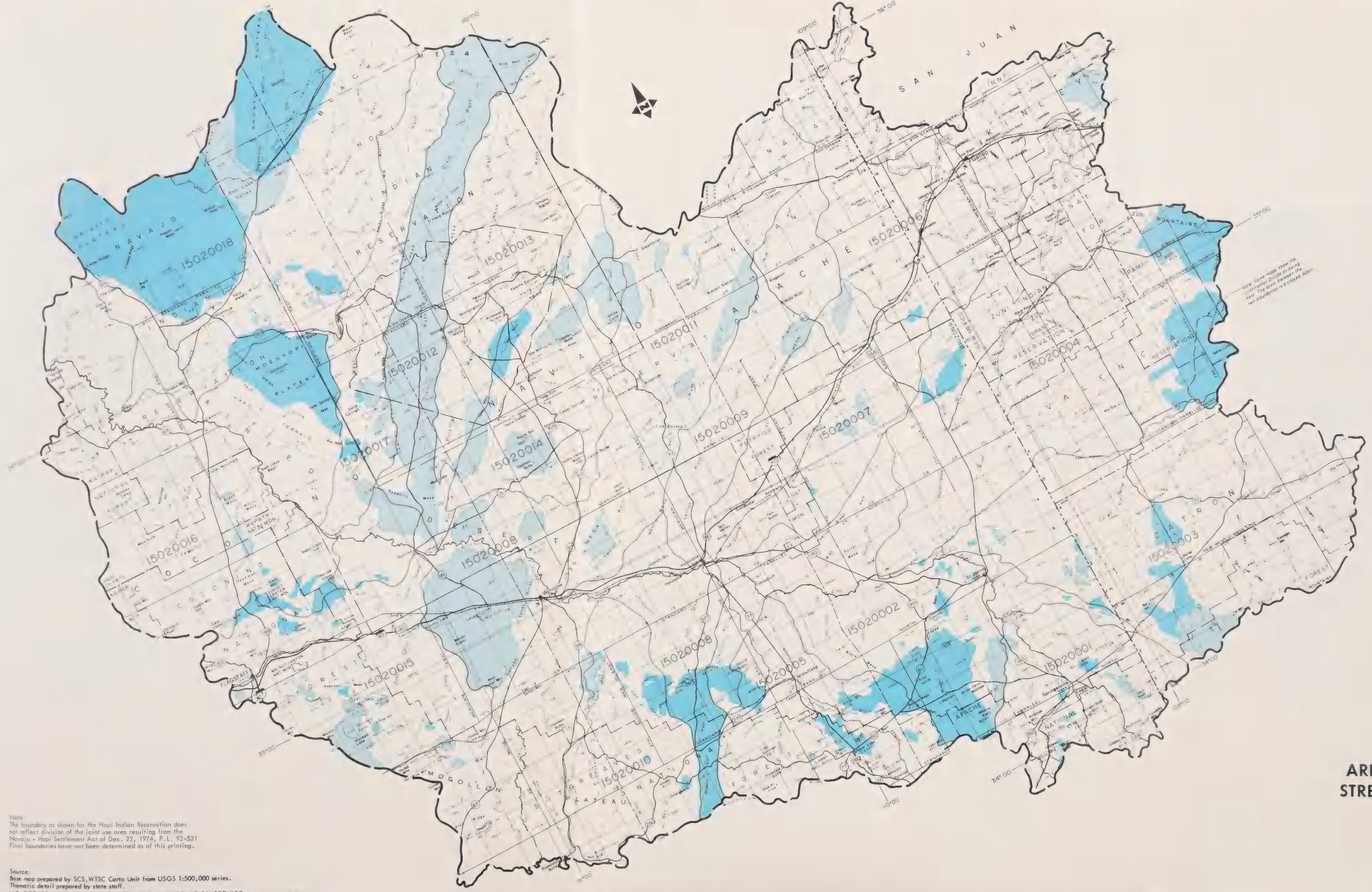
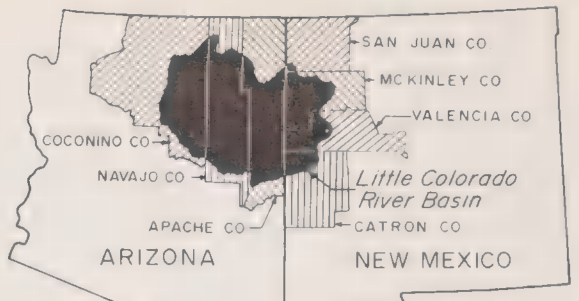




LOCATION MAP

LEGEND

Areas Of External Drainage Only During High Stream Flow

Areas Of No External Drainage

BY
ARIZONA WATER COMMISSION
NEW MEXICO STATE ENGINEER
AND
U.S. DEPARTMENT OF AGRICULTURE

AREAS WHICH CONTRIBUTE LITTLE OR NO STREAM FLOW TO LITTLE COLORADO RIVER

LITTLE COLORADO RIVER BASIN

ARIZONA AND NEW MEXICO

SEPTEMBER 1979

10 0 10 20 MILES

SCALE 1:1,000,000

Note:
The boundary as shown for the Hopi Indian Reservation does not reflect division of the joint use area resulting from the Navajo - Hopi Settlement Act of Dec. 22, 1974, P.L. 93-531 Final boundaries have not been determined as of this printing.

Source:
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series.
Thematic detail prepared by state staff.

U.S DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE USDA SCS-PORTLAND OR 1979

M7-EN-23833-6

LOCATION MAP

DISSOLVED-SOLIDS CONCENTRATION, IN MILLIGRAMS PER LITER, IN GROUND WATER IN AREAS WHERE WELLS WILL YIELD AT LEAST 25 GALLONS PER MINUTE.

- Less than 500
- 500-1000
- 1000-1500
- 1500-3000
- 3000-10,000

Areas where wells will not yield at least 25 gallons per minute.

(100-500) APPROXIMATE PUMPING-LEVEL ZONE-Numbers indicate approximate pumping level, in feet below land surface, after 100 days of continuous pumping at 25 gallons per minute.

Sheets 1, 2, 3, and 4 were compiled by the U.S. Geological Survey at the request of the U.S. Soil Conservation Service to aid in the determination of the potential for ground-water development in the Little Colorado River basin. The maps are intended as preliminary guides for the development of ground water in sufficient quantity and of suitable quality for irrigation, municipal, and industrial uses.

The Little Colorado River basin is in the Colorado Plateaus physiographic province of Fenneman (1931), and most of the area receives only 8 to 12 inches per year of precipitation. High areas that border the basin, however, may receive as much as 30 inches per year of precipitation—mainly in the form of snow. Recharge to the aquifers is from the infiltration of rainfall, snowmelt, and streamflow. Streamflow is mainly ephemeral and generally is sediment laden, although reaches of some streams have perennial flow sustained by ground-water discharge. Chemical quality of the water varies greatly from place to place in the basin, from aquifer to aquifer, and vertically within an aquifer.

The maps show areas in which it is estimated that at least 25, 75, 200, or 500 gallons per minute of water can be obtained from properly constructed wells. The maps also show the approximate pumping level that would exist after 100 days of continuous pumping at the indicated rate and the approximate dissolved-solids concentration in the water. These estimates are based on several hundred well tests of varying reliability and on several thousand chemical analyses of water from wells. Where sufficient data were available, the estimates were extrapolated over large areas; areas labeled "Insufficient Data" on the maps are those in which well-yield data were insufficient for extrapolation. Wells were not considered capable of sustaining the yields and quality shown on the maps if the following limits would be exceeded: (1) well depth would exceed 3,500 feet below the land surface, (2) pumping level would exceed 2,000 feet below the land surface after 100 days of continuous pumping, or (3) water would contain more than 10,000 milligrams per liter dissolved solids. The maps show only ranges of dissolved solids, and the presence of individual constituents that may affect the usability of the water is not considered.

A field investigation will be needed to determine the feasibility of drilling a well at a particular site. Factors such as well depth, well spacing, well construction, water chemistry, and local geologic conditions must be evaluated for each site.

SELECTED REFERENCES
(See Sheets 2, 3, and 4 of 4)

(25 GPM)

AVAILABILITY OF GROUNDWATER FOR IRRIGATION, MUNICIPAL, OR INDUSTRIAL USE

LITTLE COLORADO RIVER BASIN
ARIZONA AND NEW MEXICO

Compiled by S. G. Brown, U.S. Geological Survey

FEBRUARY 1980

10 0 10 20 MILES
SCALE 1:1,000,000

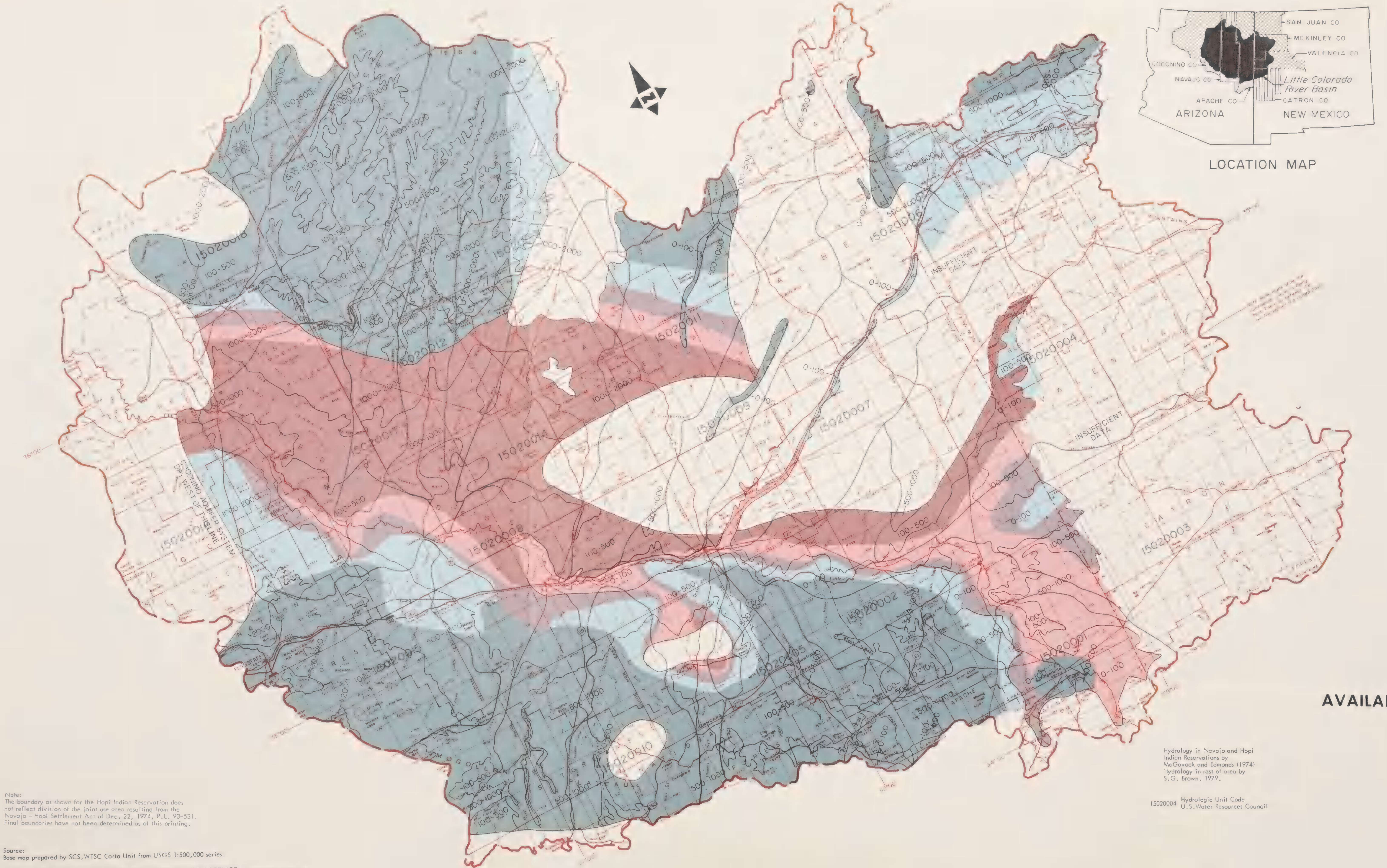
Hydrology in Navajo and Hopi Indian Reservations by McGavock and Edmonds (1974). Hydrology in rest of area by S.G. Brown, 1979.

15020004 Hydrologic Unit Code U.S. Water Resources Council

Note:
The boundary as shown for the Hopi Indian Reservation does not reflect the division of the joint use area resulting from the Navajo-Hopi Settlement Act of Dec. 22, 1974, P.L. 93-531. Final boundaries have not been determined as of this printing.

Source:
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series.

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE USDA-SCS-PORTLAND OR 1980



LOCATION MAP

DISSOLVED-SOLIDS CONCENTRATION, IN MILLIGRAMS PER LITER, IN GROUND WATER IN AREAS WHERE WELLS WILL YIELD AT LEAST 75 GALLONS PER MINUTE.

- Less than 500
- 500–1000
- 1000–1500
- 1500–3000
- 3000–10,000

Areas where wells will not yield at least 75 gallons per minute.

500-1000 APPROXIMATE PUMPING-LEVEL ZONE–Numbers indicate approximate pumping level, in feet below land surface, after 100 days of continuous pumping at 75 gallons per minute.

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(75 GPM)

AVAILABILITY OF GROUNDWATER FOR IRRIGATION, MUNICIPAL, OR INDUSTRIAL USE

LITTLE COLORADO RIVER BASIN
ARIZONA AND NEW MEXICO

Compiled by S. G. Brown, U.S. Geological Survey

FEBRUARY 1980

10 0 10 20 30 40 50 60 MILES
SCALE 1:1,000,000

Hydrology in Navajo and Hopi Indian Reservations by McGavock and Edmonds (1974)
Hydrology in rest of area by S.G. Brown, 1979.

15020004 Hydrologic Unit Code
U.S. Water Resources Council

Note:
The boundary as shown for the Hopi Indian Reservation does not reflect division of the joint use area resulting from the Navajo – Hopi Settlement Act of Dec. 22, 1974, P.L. 93-531. Final boundaries have not been determined as of this printing.

Source:
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series.

U S DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE USDA-SCS-PORTLAND OR 1977

M7-EN-23833-10

LOCATION MAP

DISSOLVED-SOLIDS CONCENTRATION, IN MILLIGRAMS PER LITER, IN GROUND WATER IN AREAS WHERE WELLS WILL YIELD AT LEAST 200 GALLONS PER MINUTE.

- Less than 500
- 500-1000
- 1000-1500
- 1500-3000
- 3000-10,000

Areas where wells will not yield at least 200 gallons per minute.

0-100 APPROXIMATE PUMPING-LEVEL ZONE-Numbers indicate approximate pumping level, in feet below land surface, after 100 days of continuous pumping at 200 gallons per minute.

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Note:
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Hydrology in Navajo and Hopi Indian Reservations by McGavock and Edmonds (1974) Hydrology in rest of area by S.G. Brown, 1979.

15020004 Hydrologic Unit Code U.S. Water Resources Council

(200 GPM)

AVAILABILITY OF GROUNDWATER FOR IRRIGATION, MUNICIPAL, OR INDUSTRIAL USE

LITTLE COLORADO RIVER BASIN
ARIZONA AND NEW MEXICO

Compiled by S. G. Brown, U.S. Geological Survey

FEBRUARY 1980

10 0 10 20 MILES
SCALE 1:1,000,000

Source:
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series.

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE USDA-SCS-PORTLAND OR 1980

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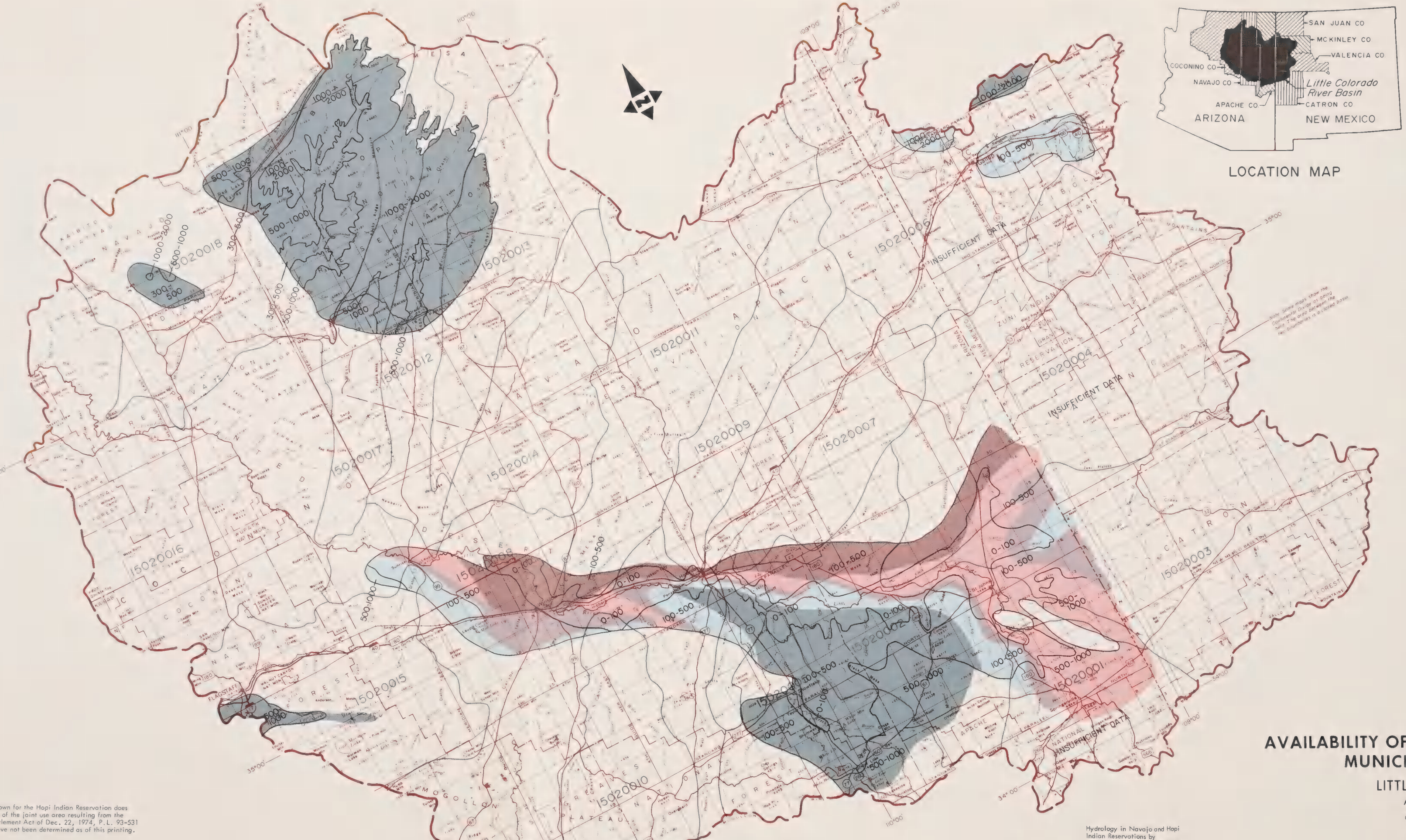

LOCATION MAP

DISSOLVED-SOLIDS CONCENTRATION, IN MILLIGRAMS PER LITER, IN GROUND WATER IN AREAS WHERE WELLS WILL YIELD AT LEAST 500 GALLONS PER MINUTE.

- Less than 500
- 500-1000
- 1000-1500
- 1500-3000
- 3000-10,000

Areas where wells will not yield at least 500 gallons per minute.

100-500 APPROXIMATE PUMPING-LEVEL ZONE-Numbers indicate approximate pumping level, in feet below land surface, after 100 days of continuous pumping at 500 gallons per minute.

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(500 GPM)

AVAILABILITY OF GROUNDWATER FOR IRRIGATION, MUNICIPAL, OR INDUSTRIAL USE

LITTLE COLORADO RIVER BASIN
ARIZONA AND NEW MEXICO

Compiled by S. G. Brown, U.S. Geological Survey

FEBRUARY 1980

10 0 10 20 MILES

SCALE 1:1,000,000

Hydrology in Navajo and Hopi Indian Reservations by McGavock and Edmonds (1974)
Hydrology in rest of area by S.G. Brown, 1979.

15020004 Hydrologic Unit Code
U.S. Water Resources Council

Note:
The boundary as shown for the Hopi Indian Reservation does not reflect division of the joint use area resulting from the Navajo - Hopi Settlement Act of Dec. 22, 1974, P.L. 93-531
Final boundaries have not been determined as of this printing.

Source:
Base map prepared by SCS, WTSC Carto Unit from AMS 1:500,000 series.

Although a large part of the precipitation that falls on the mountains is lost to the atmosphere by evaporation or transpiration, a part is infiltrated directly into the overlying rocks and becomes a part of the recharge to the groundwater reservoir. A larger percentage of the precipitation that occurs as snow becomes recharged than that occurring as rainfall. This is mainly due to the slow rates of snowmelt.

Most of the precipitation that infiltrates the Basin's soils is evaporated directly from the upper soil zone or is transpired by vegetation. Only a small percentage percolates downward to the groundwater reservoir. A small portion of the water in canals and that applied to irrigated fields is recharged to the groundwater system. This process is referred to as incidental recharge; i.e., it is incidental to use, and includes both surface water and groundwater used for irrigation, although the recharge from pumped groundwater could simply be considered a credit against pumpage.

The amount of water recharged to the groundwater system as a result of infiltration of channel streamflow or as leakage from manmade or natural reservoirs is unknown. Streamflow records, however, indicate that some channel losses do occur, and it is reasonable to expect that some of this water becomes a part of the groundwater system. It is also reasonable to expect that some of the water which leaks from the manmade reservoirs or naturally closed basins is recharged to the groundwater reservoir.

In general, the direction of movement of groundwater in the Basin is from the margins towards the Little Colorado River or the central part of the Basin. It then moves north-northwest to the Colorado River. About two-thirds of the groundwater moving through the Basin is discharged at Blue Spring or one of the several other springs located near the Basin's outlet. Most of the water discharged at Blue Spring is from the C aquifer system. A small amount of water from the Black Mesa area moves north, out of the Basin, through the Navajo Sandstone and discharges into Chinle and Moenkopi Washes.

Other processes of groundwater discharge from the Basin include: (1) evaporation, (2) transpiration, and (3) pumping. Small amounts of groundwater may be discharged by direct evaporation where the water table is near the surface. In most of the study area, the water table is sufficiently below the surface to prevent any significant amount of discharge in this manner. As the depth to water approaches 10 feet, the discharge of groundwater by evaporation becomes negligible.

Natural transpiration of water from the groundwater reservoir is generally limited to that used by phreatophytes. These are plants that sink their roots to or below the capillary fringe and use groundwater for their growth and sustenance. In many areas along the stream channels, these plants are quite dense and they use thousands of acre-feet of groundwater each year.

In addition to Blue Spring, groundwater is discharged by some 900 other springs where the water table intersects the land surface or where water from deep artesian aquifers find an outlet through fractures or fault zones.

Relatively large amounts of water are also discharged from the aquifers through groundwater pumpage. Estimates indicate that over 79,000 acre-feet were withdrawn from the aquifers of the Basin during 1975 (Table 5-3). Projected groundwater withdrawals for years 1990, 2000 and 2020 are shown in Tables 5-4, 5-5 and 5-6. Detailed explanation of these withdrawals are given in the"Water Budget Description Section"of this report which follows. The effects of groundwater pumping in the southern part of Navajo County, (i.e., for the Holbrook, Snowflake and approximately half of the Chevelon water use areas) can be noted on the drawdown maps shown in Figures 5-11 and 5-12. These maps are a product of the groundwater model developed by the U.S. Geological Survey for the county. The maps show the present (1975) and projected (2000) drawdowns for the study area.

For the most part, the simulated water-level declines appear to be a reasonable estimate of those which might be expected to result from the projected pumpage. However, the following items should be regarded as having an unknown or questionable effect on the ability of the model to accurately simulate the actual conditions:

1. The simulated pumpage in T.15 N., R.23 E. (Hay Hollow Area) is very near the eastern boundary of the model. Since 1972, which was the last year used to calibrate the model, the pumpage has increased by 500 percent and the simulated declines are much larger than the measured delcines. The reasons for this difference is as follows: (a) The boundary of the model is simulated as a constant flux boundary. The increase in pumpage has increased the flux across the boundary; the increase in flux is not accounted for in the model. (b) As a result of declines, vertical leakage may have been induced from the upper confining bed; however, leakage was not simulated by the model in this area.

2. Simulated pumpage in T.18 N., R.15 E. (Winslow Area) is near the western boundary and the model-generated declines may be in error owing to the same reasons stated in item one above.

3. Two constant head boundaries are used to simulate inflow to the aquifer; one along the Little Colorado River between Silver Creek and the Puerco River, and one along the southern boundary of the model. Simulated pumpage intercepted both of these constant head boundaries and increased the amount of simulated inflow to the aquifer, especially the one along the Little Colorado River. However, the increase in simulated inflow is only about 2,500 acre-feet per year or about 5 percent of the annual water budget.

4. Spring discharge along Clear Creek, Chevelon Creek, Silver Creek and the Little Colorado River near Joseph City is simulated as pumping wells and is assumed to be constant for 1972 to 2020. Eventually, part of this spring discharge will be intercepted by pumping wells. Therefore, the actual flow of some springs will decrease; the rate of decrease is not known; and, for modeling purposes, is assumed to be constant.

Areas of the New Mexico portion of the Little Colorado River Basin have been declared an "underground water basin." In general, the New Mexico State Engineer declares a "basin" when it appears that new demands, if met,

EXPLANATION

——10—— Approximate line of equal simulated water-level decline - 10 feet interval

———— Boundary of Mathematical Model

FIGURE 5-11: SIMULATED WATER-LEVEL DECLINES IN THE COCONINO AQUIFER, 1960-1975

EXPLANATION

——10—— Approximate line of equal simulated water-level decline - 10 feet interval

———— Boundary of Mathematical Model

FIGURE 5-12: SIMULATED WATER-LEVEL DECLINES IN THE COCONINO AQUIFER, 1960-2000

might impair existing rights. The process of declaring a "basin" includes naming it, describing its boundaries, and holding public hearings. After an "underground water basin" has been declared, the following conditions, as a minimum, must be met to obtain a new appropriation:

1. A permit from the State Engineer is necessary prior to drilling a well.

2. The drilling must be done by a driller licensed by the State Engineer.

3. Any new appropriation will not impair existing rights; exceptions are applications for domestic and livestock water purposes.

WATER BUDGET DESCRIPTIONS

Surface water budgets (including pumped groundwater) for the selected water use areas and the total Basin are shown in Tables 5-3, 5-4, 5-5 and 5-6, and are illustrated on the Sruface Water Budget map following the tables. These budgets are based on best estimated of the total water supply, uses and outflow for each water use area. Both present and projected budgets are shown in the tables, but only the 1975 water budgets are illustrated on the map.

For the purposes of this report, the available water supply is defined as the average annual runoff (including spring flow) plus groundwater pumpage. For this reason, the available water supply will increase as the volume of groundwater pumped increases. The stated definition for water supply necessitates that channel losses be shown in the water budget tables as a water use.

Water uses are based on withdrawal requirements. These requirements may be defined as the total quantity of water required, at the point of diversion, to satisfy a given need. Withdrawal requirements were used in lieu of depletion requirements, due to a lack of data to adequately separate surface water return flows from other sources of supply. Also, only a simplified accounting system was used between surface water and groundwater supplies. The total water withdrawn for a purpose, therefore, is charged to that purpose.

The following are general descriptions of Annual Water Budgets for each of the individual water use areas (WUA) and for the Total Basin.

ARIZONA

Black Mesa (BLM)

The Black Mesa WUA is one of the largest with respect to drainage area size, but it has a relatively small water supply. Within Arizona, it ranks third from the bottom with reference to total supply and use. The two other low water use areas in Arizona are Tuba City and Kaibito Plateau.

TABLE 5-3: AVERAGE ANNUAL WATER BUDGETS - 1975 1/

LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO

WATER USE AREA	WATER SUPPLY (AC-FT)				WATER USE (AC-FT)								
	PUMPED GROUND-WATER (AC-FT)	NET SURFACE RUNOFF (AC-FT)	SURFACE INFLOW (AC-FT)	TOTAL SUPPLY (AC -FT)	IRRIGATION AND LIVESTOCK (AC-FT)	M&I & RURAL DOMESTIC (AC-FT)	MAJOR INDUSTRIAL (AC-FT)	STEAM ELECTRIC (AC-FT)	FISH & WILDLIFE (AC-FT)	RECREATION (AC-FT)	CHANNEL LOSS (AC-FT)	TOTAL WITHDRAWAL (AC-FT)	SURFACE OUTFLOW 2/ (AC-FT)
ARIZONA													
(BLM) Black Mesa	5,050	22,800		27,850	2,250	900	4,100		150			7,400	20,450
(BOD) Bodaway Mesa	50	83,550	56,550	140,150	200	50			200			450	139,700
(CDI) Canyon Diablo	2,750	13,400	135,800	151,950	9,750	1,700			3,750	5,850	6,400	27,450	124,500
(CHV) Chevelon	200	115,650	37,850	153,700	1,900	200	3,050		1,850	1,200	3,200	11,400	142,300 3/
(CHN) Chinle	1,450	15,250	4,200	20,900	4,400	1,400			100	50		5,950	14,950
(CON) Concho	7,850	3,800	17,700	29,350	15,300	100		50 4/	750			16,200	13,150
(HOL) Holbrook	16,600	9,000	74,250	99,850	14,000	1,550		3,300	2,000		4,700	25,550	74,300
(HOP) Hopi	550	15,450	67,200	83,200	2,200	500			1,800		18,650	23,150	60,050
(KAI) Kaibito Plateau	100	1,650		1,750	300	100						400	1,350
(PRZ) Puerco-Zuni	1,950	27,750	27,150	56,850	3,300	150			1,300			4,750	52,100
(SFP) San Francisco Peaks	2,300	102,200	123,800	228,300	1,800	5,550			450	200	9,000	17,000	211,300
(STJ) St. Johns	1,200	6,650	28,550	36,400	27,200	250		200	300	500		28,450	7,950
(SNO) Snowflake	29,300	14,550	10,600	54,450	23,600	700	15,750		250	1,550		41,850	12,600
(TUB) Tuba City	950	250	10,650	11,850	900	950			200			2,050	9,800
(WHM) White Mountains	2,250	70,100		72,350	29,200	1,950	450		1,250	800		33,650	38,700 5/
TOTAL ARIZONA	72,550	502,050	30,900 6/	605,500 7/	136,300	16,050	23,350	3,550	14,350	10,150	41,950	245,700	359,800 10/
NEW MEXICO													
(CAR) Carrizo Wash	100	7,600		7,700	800	50			450			1,300	6,400
(UPR) Upper Puerco	5,000	20,550		25,550	2,150	4,250	700		500	50		7,650	17,900
(ZUN) Zuni	1,500	19,450		20,950	12,200	200	1,150		150	650		14,350	6,600
TOTAL NEX MEXICO	6,600	47,600		54,200 8/	15,150	4,500	1,850		1,100	700		23,300	30,900 6/
TOTAL BASIN	79,150	549,650		628,800 9/	151,450	20,550	25,200	3,550	15,450	10,850	41,950	269,000	359,800 10/

1/ Includes pumped groundwater.
2/ Surface Outflow equals Total Supply minus Total Withdrawal.
3/ Includes 10,900 acre-feet pumped from Blue Ridge Reservoir and exported to the East Verde River in the Salt River Basin.
4/ This water is exported to the STJ Water Use Area for use by the Coronado Steam Electric Power Plant near St. Johns.
5/ Includes 3,300 acre-feet pumped from Show Low Lake and exported to Forestdale Creek in the Salt River Basin.
6/ Estimated surface water inflow to Arizona (and/or outflow from New Mexico) portion of Basin. (see Water Budget map).
7/ 8/ 9/ These figures represent the total water supply for Arizona, New Mexico, and Total Basin, respectively, and are the sum of net surface runoff plus pumped groundwater. For the Arizona portion of the Basin it also includes the inflow from New Mexico, (see footnote 6).
10/ Estimated outflow from the Basin including the flow at the Basin's outlet plus 14,200 acre-feet exported from the Basin as noted in footnotes 3 & 5.

TABLE 5-4: AVERAGE ANNUAL WATER BUDGETS - 1990 1/

LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO

WATER USE AREA	WATER SUPPLY (AC-FT)				WATER USE (AC-FT)								2/
	PUMPED GROUND-WATER (AC-FT)	NET SURFACE RUNOFF (AC-FT)	SURFACE INFLOW (AC-FT)	TOTAL SUPPLY (AC-FT)	IRRIGATION AND LIVESTOCK (AC-FT)	M&I & RURAL DOMESTIC (AC-FT)	MAJOR INDUSTRIAL (AC-FT)	STEAM ELECTRIC (AC-FT)	FISH & WILDLIFE (AC-FT)	RECREATION (AC-FT)	CHANNEL LOSS (AC-FT)	TOTAL WITHDRAWAL (AC-FT)	SURFACE OUTFLOW (AC-FT)
ARIZONA													
(BLM) Black Mesa	5,550	22,800		28,350	2,250	1,400	4,100		150			7,900	20,450
(BOD) Bodaway Mesa	100	83,550	52,000	135,650	200	100			200			500	135,150
(CDI) Canyon Diablo	3,400	13,400	131,900	148,700	9,750	2,350			3,750	5,850	6,400	28,100	120,600
(CHV) Chevelon	300	115,650	34,050	150,000	1,900	300	3,050		1,850	1,300	3,200	11,600	138,400 3/
(CHN) Chinle	1,900	15,250	3,500	20,650	4,400	1,850			100	750		7,100	13,550
(CON) Concho	12,750	3,800	13,500	30,050	15,300	150		4,900 4/	750			21,100	8,950
(HOL) Holbrook	27,400	9,000	67,150	103,550	14,000	2,150		13,500	2,000	550	4,700	36,900	66,650
(HOP) Hopi	900	15,450	62,650	79,000	2,200	850			1,800		18,650	23,500	55,500
(KAI) Kaibito Plateau	200	1,650		1,850	300	200						500	1,350
(PRZ) Puerco-Zuni	2,100	27,750	20,050	49,900	3,300	300			1,300			4,900	45,000
(SFP) San Francisco Peaks	4,650	102,200	119,900	226,750	1,800	7,900			450	200	9,000	19,350	207,400
(STJ) St. Johns	21,950	6,650	28,550	57,150	27,200	600		20,600	300	500		49,200	7,950
(SNO) Snowflake	29,800	14,550	10,600	54,950	23,600	1,200	15,750		250	1,550		42,350	12,600
(TUB) Tuba City	1,500	250	10,650	12,400	900	1,500			200			2,600	9,800
(WHM) White Mountains	3,500	70,100		73,600	29,200	3,200	450		1,250	800		34,900	38,700 5/
TOTAL ARIZONA	116,000	502,050	23,800 6/	641,850 7/	136,300	24,050	23,350	39,000	14,350	11,500	41,950	290,500	351,350 10/
NEW MEXICO													
(CAR) Carrizo Wash	1,000	7,600		8,600	750	50	950		450			2,200	6,400
(UPR) Upper Puerco	10,250	20,550		30,800	2,050	8,200	2,500		3,000	50		15,800	15,000
(ZUN) Zuni	12,800	19,450		32,250	23,950	1,850	1,650		1,750	650		29,850	2,400
TOTAL NEX MEXICO	24,050	47,600		71,650 8/	26,750	10,100	5,100		5,200	700		47,850	23,800 6/
TOTAL BASIN	140,050	549,650		689,700 9/	163,050	34,150	28,450	39,000	19,550	12,200	41,950	338,350	351,350 10/

1/ Includes pumped groundwater.
2/ Surface Outflow equals Total Supply minus Total Withdrawal.
3/ Includes 10,900 acre-feet pumped from Blue Ridge Reservoir and exported to the East Verde River in the Salt River Basin.
4/ This water is exported to the STJ Water Use Area for use by the Coronado Steam Electric Power Plant near St. Johns.
5/ Includes 3,300 acre-feet pumped from Show Low Lake and exported to Forestdale Creek in the Salt River Basin.
6/ Estimated surface water inflow to Arizona (and/or outflow from New Mexico) portion of Basin.
7/ 8/ 9/ These figures represent the total water supply for Arizona, New Mexico, and Total Basin, respectively, and are the sum of net surface runoff plus pumped groundwater. For the Arizona portion of the Basin it also includes the inflow from New Mexico, (see footnote 6).
10/ Estimated outflow from the Basin including the flow at the Basin's outlet plus 14,200 acre-feet exported from the Basin as noted in foo-notes 3 & 5

TABLE 5-5: AVERAGE ANNUAL WATER BUDGETS - 2000 [1]

LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO

WATER USE AREA	WATER SUPPLY (AC-FT)				WATER USE (AC-FT)								
	PUMPED GROUND-WATER (AC-FT)	NET SURFACE RUNOFF (AC-FT)	SURFACE INFLOW (AC-FT)	TOTAL SUPPLY (AC-FT)	IRRIGATION AND LIVESTOCK (AC-FT)	M&I & RURAL DOMESTIC (AC-FT)	MAJOR INDUSTRIAL (AC-FT)	STEAM ELECTRIC (AC-FT)	FISH & WILDLIFE (AC-FT)	RECREATION (AC-FT)	CHANNEL LOSS (AC-FT)	TOTAL WITHDRAWAL (AC-FT)	SURFACE[2] OUTFLOW (AC-FT)
ARIZONA													
(BLM) Black Mesa	5,900	22,800		28,700	2,250	1,750	4,100		150			8,250	20,450
(BOD) Bodaway Mesa	150	83,550	51,050	134,750	200	150			200			550	134,200
(CDI) Canyon Diablo	3,950	13,400	130,950	148,300	9,750	2,900			3,750	5,850	6,400	28,650	119,650
(CHV) Chevelon	400	115,650	33,100	149,150	1,900	400	3,050		1,850	1,300	3,200	11,700	137,450[3]
(CHN) Chinle	2,350	15,250	3,000	20,600	4,400	2,300			100	750		7,550	13,050
(CON) Concho	12,750	3,800	13,600	30,150	15,300	150		4,900[4]	750			21,100	9,050
(HOL) Holbrook	27,850	9,000	65,250	102,100	14,000	2,600		13,500	2,000	550	4,700	37,350	64,750
(HOP) Hopi	1,200	15,450	61,700	78,350	2,200	1,150			1,800		18,650	23,800	54,550
(KAI) Kaibito Plateau	300	1,650		1,950	300	300						600	1,350
(PRZ) Puerco-Zuni	2,150	27,750	18,150	48,050	3,300	350			1,300			4,950	43,100
(SFP) San Francisco Peaks	6,150	102,200	118,950	227,300	1,800	9,400			450	200	9,000	20,850	206,450
(STJ) St. Johns	27,450	6,650	28,650	62,750	27,200	700		26,000	300	500		54,700	8,050
(SNO) Snowflake	30,150	14,550	10,600	55,300	23,600	1,550	15,750		250	1,550		42,700	12,600
(TUB) Tuba City	1,900	250	10,650	12,800	900	1,900			200			3,000	9,800
(WHM) White Mountains	4,350	70,100		74,450	29,200	4,050	450		1,250	800		35,750	38,700[5]
TOTAL ARIZONA	127,000	502,050	21,900[6]	650,950[7]	136,300[10]	29,650	23,350	44,400	14,350	11,500	41,950	301,500	349,450[11]
NEW MEXICO													
(CAR) Carrizo Wash	1,650	7,600		9,250	700	50	1,550		450			2,750	6,500
(UPR) Upper Puerco	4,650	20,550	7,500[12]	32,700	1,300	10,850	2,900		4,600	50		19,700	13,000
(ZUN) Zuni	17,150	19,450		36,600	23,500	2,550	1,950	2,300	3,250	650		34,200	2,400
TOTAL NEX MEXICO	23,450	47,600	7,500[12]	78,550[8]	25,500	13,450	6,400	2,300	8,300	700		56,650	21,900[6]
TOTAL BASIN	.150,450	549,650	7,500[12]	707,600[9]	161,800	43,100	29,750	46,700	22,650	12,200	41,950	358,150	349,450[11]

1/ Includes pumped groundwater.
2/ Surface Outflow equals Total Supply minus Total Withdrawal.
3/ Includes 10,900 acre-feet pumped from Blue Ridge Reservoir and exported to the East Verde River in the Salt River Basin.
4/ This water is exported to the STJ Water Use Area for use by the Coronado Steam Electric Power Plant near St. Johns.
5/ Includes 3,300 acre-feet pumped from Show Low Lake and exported to Forestdale Creek in the Salt River Basin.
6/ Estimated surface water inflow to Arizona (and/or outflow from New Mexico) portion of Basin.
7/ 8/ 9/ These figures represent the total water supply for Arizona, New Mexico, and Total Basin, respectively, and are the sum of net surface runoff plus pumped groundwater. For the Arizona portion of the Basin it also includes the inflow from New Mexico (see footnote 6), and in New Mexico 7,500 acre-feet are imported from San Juan Basin. (see footnote 12).
10/ Although Table 1-4, Appendix II, Section 1, Irrigation shows a potential reduction in withdrawals for irrigation in Arizona (due to increased efficiencies in projected periods 2000 and 2020); it was assumed in the water budget analysis that the total withdrawals for this purpose would remain the same, and that any water saved would be used to increase crop yields or to irrigate native grasses.
11/ Estimated outflow from the Basin including the flow at the Basin's outlet plus 14,200 acre-feet exported from the Basin as noted in footnotes 3 & 5.
12/ Surface water imported from the San Juan River Basin for use in Gallup, Nes Mexico.

TABLE 5-6: AVERAGE ANNUAL WATER BUDGETS - 2020 1/

LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO

WATER USE AREA	WATER SUPPLY (AC-FT)				WATER USE (AC-FT)								
	PUMPED GROUND-WATER (AC-FT)	NET SURFACE RUNOFF (AC-FT)	SURFACE INFLOW (AC-FT)	TOTAL SUPPLY (AC-FT)	IRRIGATION AND LIVESTOCK (AC-FT)	M&I & RURAL DOMESTIC (AC-FT)	MAJOR INDUSTRIAL (AC-FT)	STEAM ELECTRIC (AC-FT)	FISH & WILDLIFE (AC-FT)	RECREATION (AC -FT)	CHANNEL LOSS (AC-FT)	TOTAL WITHDRAWAL (AC-FT)	SURFACE 2/ OUTFLOW (AC-FT)
ARIZONA													
(BLM) Black Mesa	6,600	22,800		29,400	2,250	2,450	4,100		150			8,950	20,450
(BOD) Bodaway Mesa	200	83,550	51,050	134,800	200	200			200			600	134,200
(CDI) Canyon Diablo	4,550	13,400	130,950	148,900	9,750	3,500			3,750	5,850	6,400	29,250	119,650
(CHV) Chevelon	500	115,650	33,100	149,250	1,900	500	3,050		1,850	1,300	3,200	11,800	137,450 3/
(CHN) Chinle	3,300	15,250	3,000	21,550	4,400	3,250			100	750		8,500	13,050
(CON) Concho	12,800	3,800	13,700	30,300	15,300	200		4,900 4/	750			21,150	9,150
(HOL) Holbrook	28,400	9,000	65,250	102,650	14,000	3,150		13,500	2,000	550	4,700	37,900	64,750
(HOP) Hopi	1,650	15,450	61,700	78,800	2,200	1,600			1,800		18,650	24,250	54,550
(KAI) Kaibito Plateau	400	1,650		2,050	300	400						700	1,350
(PRZ) Puerco-Zuni	2,200	27,750	18,150	48,100	3,300	400			1,300			5,000	43,100
(SFP) San Francisco Peaks	7,650	102,200	118,950	228,800	1,800	10,900			450	200	9,000	22,350	206,450
(STJ) St. Johns	27,600	6,650	28,750	63,000	27,200	850		26,000	300	500		54,850	8,150
(SNO) Snowflake	30,500	14,550	10,600	55,650	23,600	1,900	15,750		250	1,550		43,050	12,600
(TUB) Tuba City	2,500	250	10,650	13,400	900	2,500			200			3,600	9,800
(WHM) White Mountains	5,200	70,100		75,300	29,200	4,900	450		1,250	800		36,600	38,700 5/
TOTAL ARIZONA	134,050	502,050	21,900 6/	658,000 7/	136,300 10/	36,700	23,350	44,400	14,350	11,500	41,950	308,550	349,450 11/
NEW MEXICO													
(CAR) Carrizo Wash	5,550	7,600		13,150	650	50	5,400		450			6,550	6,600
(UPR) Upper Puerco	17,100	20,550	7,500 12/	45,150	1,250	22,550	3,800		4,600	50		32,250	12,900
(ZUN) Zuni	24,250	19,450		43,700	21,650	5,650	3,700	6,400	3,250	650		41,300	2,400
TOTAL NEX MEXICO	46,900	47,600	7,500 12/	102,000 8/	23,550	28,250	12,900	6,400	8,300	700		80,100	21,900 6/
TOTAL BASIN	180,950	549,650	7,500 12/	738,100 9/	159,850	64,950	36,250	50,800	22,650	12,200	41,950	388,650	349,450 11/

1/ Includes pumped groundwater.
2/ Surface Outflow equals Total Supply minus Total Withdrawals.
3/ Includes 10,900 acre-feet pumped from Blue Ridge Reservoir and exported to the East Verde River in the Salt River Basin.
4/ This water is exported to the STJ Water Use Area for use by the Coronado Steam Electric Power Plant near St. Johns.
5/ Includes 3,300 acre-feet pumped from Show Low Lake and exported to Forestdale Creek in the Salt River Basin.
6/ Estimated surface water inflow to Arizona (and/or outflow from New Mexico) portion of Basin.
7/ 8/ 9/ These figures represent the total water supply for Arizona, New Mexico, and Total Basin, respectively, and are the sum of net surface runoff plus pumped groundwater. For the Arizona portion of the Basin it also includes the inflow from New Mexico (see footnote 6), and in New Mexico 7,500 acre-feet are imported from San Juan Basin. (see footnote 12.)

10/ Although Table 1-4, Appendix II, Section 1, Irrigation shows a potential reduction in withdrawals for irrigation in Arizona (due to increased efficiencies in projected periods 2000 and 2020); it was assumed in the water budget analysis that the total withdrawals for this purpose would remain the same, and that any water saved would be used to increase crop yields or to irrigate native grasses.
11/ Estimated outflow from the Basin including the flow at the Basin's outlet plus 14,200 acre-feet exported from the Basin as noted in footnotes 3 & 5.
12/ Surface water imported from the San Juan River Basin for use in Gallup, New Mexico.

Excluding surface water outflows, the total withdrawal in 1975 was estimated to be 7,400 acre-feet. This water was used for irrigation and livestock, municipal and industrial (M&I) and rural domestic, and major industry (mineral production), Table 5-3. These uses were supplied mostly from groundwater. The only surface water developments have been for livestock.

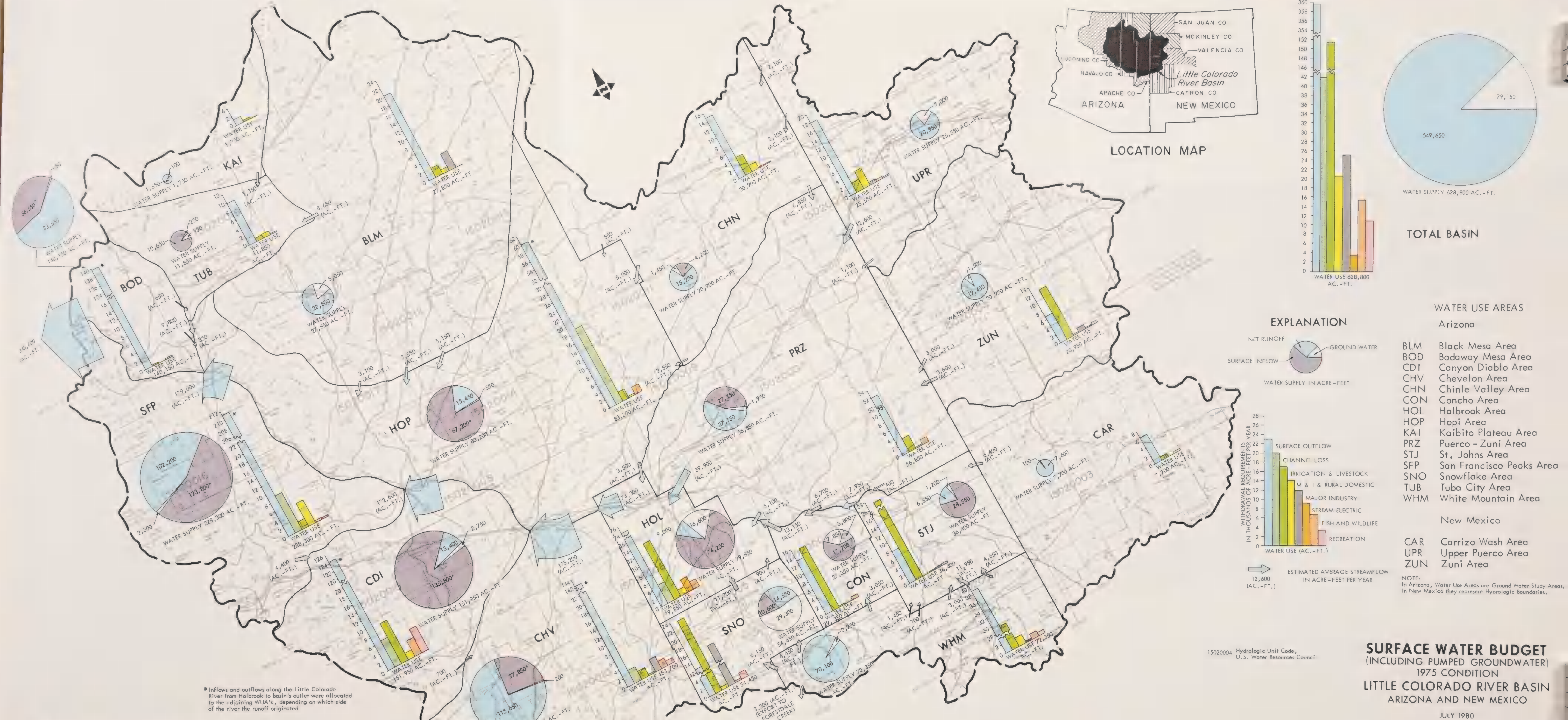
Although most of the surface water is discharged from the study area, some streams in the Black Mesa area contribute little or no flow to the Little Colorado River. These include Oraibi Wash, Shonoto Wash, Moenkopi Plateau and some other minor drainages. (See map entitled, "Areas Which Contribute Little or No Streamflow to the Little Colorado River.") Flows from most of these areas were not considered a viable source of water; thus, were not included in the water budget. On Orabi Wash, however, an estimate was made of the average annual runoff, and this value in included in the outflow column of the water budget tables.

Projected increases in water use within the Black Mesa study area are small. The only known increase is for M&I and rural domestic purposes. This value is expected to increase from about 900 acre-feet in 1975 to about 2,450 acre-feet by 2020. With the increase, the total estimated withdrawal from the study area in 2020 is 8,950 acre-feet, excluding surface outflows (Table 5-6).

Bodaway Mesa (BOD)

The Bodaway Mesa WUA is located on the north side of the Little Colorado River, near the Basin's outlet. With respect to drainage area size, this study region is relatively small; however, there is considerable water available to the region from flow in the Little Colorado River. Blue Spring, which effluents into the Little Colorado River a few miles upstream from its mouth accounts for a major part of this flow. The spring flow, however, is quite high in total dissolved solids; ranging from about 2,500 to 2,600 parts per million (PPM) for the combined flows. Considerable lift would also be required should it be desired to use this water, since the river channel is deeply incised at this location. The volume of flow from Blue Spring, together with other springs located in the same general area, is about 223 cfs or about 161,400 acre-feet per year. Only about half of the volume was assumed to be available to the Bodaway Mesa area; the other half is included in the San Francisco Peak's Water Budget. Other upstream surface water flows were similarly divided; flows originating to the north and east of the river were placed in the Bodaway Mesa area and those to the south and west of the river are shown in the San Francisco Peak's WUA. (See explanation given in "Introduction.")

The net water use in the Bodaway Mesa area is relatively small, consisting of only about 450 acre-feet in 1975. It includes 200 acre-feet used by livestock; 50 acre-feet used for rural domestic purposes; and 200 acre-feet used by riparian vegetation. (This latter figure is included under the Fish and Wildlife category of Table 5-3.) About 139,700 acre-feet are discharged from the WUA at the mouth of the Little Colorado River.



* Inflows and outflows along the Little Colorado River from Holbrook to basin's outlet were allocated to the adjoining WUA's, depending on which side of the river the runoff originated

Note:
The boundary as shown for the Hopi Indian Reservation does not reflect division of the joint use area resulting from the Navajo - Hopi Settlement Act of Dec. 22, 1974, P.L. 93-531. Final boundaries have not been determined as of this printing.

Source:
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series.
Thematic detail compiled by state staff.

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE USDA-SCS-PORTLAND, OR 1980

SURFACE WATER BUDGET
(INCLUDING PUMPED GROUNDWATER)
1975 CONDITION
LITTLE COLORADO RIVER BASIN
ARIZONA AND NEW MEXICO

JULY 1980

10 0 10 20 MILES
SCALE 1:1,000,000

M7-EN-23833-17

Most of the water used in the study area is furnished from surface water sources. Only about 50 acre-feet of groundwater were pumped in 1975. This water was used for rural domestic purposes as noted above. Withdrawals for these purposes are projected to increase to about 200 acre-feet per year by the year 2020.

Canyon Diablo (CDI)

The Canyon Diablo WUA is located south of the Little Colorado River in the vicinity of Winslow. Most of the water supply for this area is from surface sources. Approximately 131,400 acre-feet per year are estimated to be available along the Little Colorado River from upstream runoff. This, again, is the runoff which originates to the south and west of the river channel. Another 4,400 acre-feet are estimated to flow into the area from the San Francisco Peaks WUA along San Francisco Wash. This latter water, however, is lost, primarily through sinks, at the Canyon Diablo Dam site as explained below.

Net runoff within the study area is relatively small, especially in comparison to the amount of precipitation it receives. There is a large area surrounding Luepp Corner which yields little or no runoff to the Little Colorado River. This results from a natural depression or levee that has formed in the area along the south side of the river (see map entitled "Areas Which Contribute Little or No Streamflow to the Little Colorado River"). Also, a dam was built near the mouth of Canyon Diablo in 1967; and due to the formation of caverns or sinks upstream of the dam, only limited surface flow is known to have passed the dam since it was completed.

Excluding surface outflows (124,500 acre-feet per year), the major surface water withdrawal in the study area is for recreation. This withdrawal consists basically of evaporation from reservoirs constructed for recreational purposes. This amounted to about 5,850 acre-feet in 1975. Other evaporation losses include 2,950 acre-feet from fish and wildlife reservoirs, and 4,550 acre-feet from reservoirs used for irrigation and livestock. An additional 4,050 acre-feet of surface waters were diverted for crop production, and another 800 acre-feet were used by riparian vegetation. The remaining 100 acre-feet of surface water withdrawals were charged to livestock for drinking. About 6,400 acre-feet per year are estimated to be lost to the streambed of the Little Colorado River as water flows through the study area.

Groundwater withdrawals in the study area in 1975 were estimated to be 2,750 acre-feet. Most of this water was used for M&I and rural domestic purposes, with approximately 1,050 acre-feet being pumped for irrigation and livestock.

As in the two previous WUA's, the only projected increase in water use is for M&I and rural domestic purposes. This value is expected to increase to about 3,500 acre-feet by the year 2020. This increase will be supplied from groundwater resources.

Chevelon (CHV)

The Chevelon WUA consists basically of the Chevelon and Clear Creeks drainages, together with Phoenix Park Wash (Dry Lake) and McDonald Canyon. From the standpoint of surface runoff, this study area is one of the highest producing areas in the river basin. The average annual runoff from within the WUA has been estimated at 115,650 acre-feet per year. An additional 37,850 acre-feet of runoff are available from outside the study area. Most of the runoff, however, is discharged from the study area; either by diversion from storage (10,900 acre-feet) or by streamflow (131,400 acre-feet). The total discharge is about 142,300 acre-feet per year. Another 3,200 acre-feet per year are estimated to be lost to the Little Colorado River streambed as water flows through the study area.

Total average annual storage is estimated at 26,900 acre-feet. The diversion from storage, as noted above, is from the Blue Ridge Reservoir (located on East Clear Creek), to the East Verde River (located in the Salt River Basin). This diversion is being made by the Phelps-Dodge Corporation, a copper mining company, in exchange for water they are using in other parts of the Salt River Basin.

Another large part of the estimated storage is found in the Chevelon Canyon reservoir. This reservoir stores an estimated 8,540 acre-feet per year, and is used mostly for recreation and wildlife. The remaining surface water storage is found in some 480 livestock ponds and several other reservoirs used for irrigation, fish and wildlife, and recreation.

A new reservoir is presently being constructed on Clear Creek, downstream from an existing dam, and near the mouth of the creek. This reservoir is for recreation and irrigation and will store approximately 500 acre-feet of water.

Evaporation from the individual reservoirs is charged against the major purpose for which the reservoir(s) were constructed. Excluding surface outflows, evaporation accounts for over 75 percent (6,500 acre-feet) of the net water use in the study area. It is categorized as follows: 1,750 acre-feet, irrigation and livestock; 3,050 acre-feet, major industry (evaporation from Dry Lake and Blue Ridge Reservoirs); 500 acre-feet, fish and wildlife; and 1,200 acre-feet, recreation. Approximately 1,350 acre-feet of surface water are used by riparian vegetation, and is included in the Fish and Wildlife category of Table 5-3.

The only groundwater withdrawal in the Basin is for M&I and rural domestic purposes. This was estimated at 200 acre-feet for 1975, and is projected to increase to about 500 acre-feet by 2020. The only projected increase in surface water use is for recreation. This will result from increased evaporation on the new reservoir to be constructed for this purpose near the mouth of Clear Creek.

Chinle Valley (CHN)

The Chinle WUA is located on the Navajo Indian Reservation in the northeast corner of the Basin. The total water supply is relatively small. Under

1975 conditions, the supply was estimated at 20,900 acre-feet; 15,250 acre-feet of surface runoff; 4,200 acre-feet of surface inflow from New Mexico; and 1,450 acre-feet of pumped groundwater.

Table 5-3 shows that most of the surface water flows (14,950 acre-feet) are discharged from the study area. Some flows, however, are stored and used for beneficial purposes. The average storage was estimated at 1,300 acre-feet per year. Most of this storage is found in Ganado Lake, which stores about 1,000 acre-feet per year.

Red Lake, located on the Arizona-New Mexico state line also supplies some water to the Chinle area, which is used for irrigation. The supply from this source was estimated to be about 1,900 acre-feet per year. About 700 acre-feet of the water stored in Ganado Lake is also used for irrigation. The remaining 1,800 acre-feet of irrigation and livestock water withdrawals consist of 1,650 acre-feet of evaporation and 150 acre-feet (rounded) of water consumptively used by livestock.

Other surface water withdrawals in the study area consist of 100 acre-feet used by riparian vegetation; and about 50 acre-feet evaporated from a small recreation reservoir (Table 5-3).

Water used for M&I and rural domestic purposes in 1975 was estimated at 1,400 acre-feet, and was basically supplied from groundwater. This use is projected to increase to about 3,250 acre-feet by 2020. Most of this increase will occur in the Fort Definance-Window Rock-St. Michaels area, although rural domestic withdrawals are also expected to increase.

Surface water supplies in the study area are projected to decrease under future conditions. This will result from increased use of water from this source in New Mexico for irrigation and fish and wildlife purposes, and a decrease in surface runoff from within the area due to increased evaporation from Ganado Lake when it is enlarged for recreational purposes.

Concho (CON)

The Concho WUA is located south of the river; to the west of St. Johns. The major water withdrawal in the area is for irrigation and livestock. The total use for these purposes was estimated at 15,300 acre-feet for 1975. About half of this water was supplied from groundwater pumping and half from surface water resources. The main irrigation storage in the area is in Little Ortega Lake and Concho Lake. These two reservoirs, on the average, store about 2,250 acre-feet per year. Concho Lake is used to store water from Concho Springs, which has an estimated flow of 2.7 cfs or 1,950 acre-feet per year. Other surface water flows used for irrigation are diverted from the Little Colorado River near Hunt, where approximately 4,000 acres of native grass are flood irrigated when water is available. This use was estimated at one acre-foot per acre per year.

Water for livestock is supplied from groundwater pumping and from about 70 livestock ponds. The total withdrawal for this purpose was estimated at

322 acre-feet per year, and includes about 250 acre-feet of evaporation and 72 acre-feet of water consumptively used for drinking.

The only other significant water withdrawal is for fish and wildlife purposes. Water for these purposes include 600 acre-feet used by riparian vegetation, and 150 acre-feet estimated to be evaporated from two wildlife reservoirs - Ortega Spring Lake and Laguna Salada Sink.

Water withdrawals for steam electric power generation were small under 1975 conditions, but are projected to increase significantly in the future. Withdrawals for this purpose are expected to increase from about 50 acre-feet in 1975 to about 4,900 acre-feet by 1990, and remain constant for the other study periods (Tables 5-3, 5-4, 5-5 and 5-6). This water is not used in the study area but is exported to the St. Johns WUA for use by the Coronado Power Plant. Based on population projections, water withdrawals for M&I and rural domestic purposes will also increase; going from about 100 acre-feet in 1975 to 200 acre-feet by 2020. Similar to the situations found in other water use areas, these increases are expected to be supplied from groundwater.

Holbrook (HOL)

The Holbrook WUA includes the towns of Holbrook and Joseph City and the area lying generally to the south and east of these communities (see Water Use Areas and Gaging Station Location Map). The available water supply, under 1975 conditions, was estimated at 99,850 acre-feet; 16,600 acre-feet of groundwater; 9,000 acre-feet of local runoff; and 74,250 acre-feet of surface inflows (Table 5-3).

Surface water storage within the area is very limited, and was estimated at only 2,100 acre-feet in 1975. Most of this storage (1,800 acre-feet) is in Cholla Lake, which serves as a cooling pond for the Cholla Steam Electric Power Plant, located near Joseph City. The remaining storage is found in some 218 stock ponds and two wildlife reservoirs located in the area.

Total withdrawals within the area under 1975 conditions are shown in Table 5-3. Excluding surface outflows (74,300 acre-feet) the major water use is for agriculture (14,000 acre-feet). Most of this water (11,750 acre-feet) is supplied from groundwater resources and is used for irrigation in the Joseph City, Holbrook, Woodruff and Hay Hollow areas. Also, about 1,400 acre-feet of surface flows are diverted from the Little Colorado River for irrigation in the Woodruff and Joseph City areas. The remaining 850 acre-feet, listed under the irrigation and livestock category in Table 5-3, are charged to livestock. Most of this latter volume is evaporation from stock ponds. Only about 84 acre-feet were estimated to be consumptively used by livestock. (6)

About 4,700 acre-feet of the surface water flows are estimated to be lost to the Little Colorado River streambed. This water either recharges the groundwater reservoir or is lost in some other manner not accounted for in the water budget analysis.

Water withdrawals for M&I and rural domestic purposes are supplied from groundwater pumpage. The total pumpage for these purposes was estimated at 1,550 acre-feet for 1975. This estimate was based on data obtained from the U.S. Geological Survey. Withdrawals for these purposes are expected to increase to about 3,150 acre-feet by 2020. It is assumed that the increases will also be supplied from groundwater pumpage.

Another groundwater withdrawal that is expected to increase significantly in the future is that for steam electric power generation. This withdrawal is expected to increase from about 3,300 acre-feet in 1975 to 13,500 acre-feet by 1980. These figures include about 900 acre-feet of evaporation from Cholla Lake and the Cholla Ash ponds.

At the present time (1979), three power units are in operation (total capacity 620 megawatts), and a fourth unit is planned for 1980. The three existing units, when operating at full capacity, are projected to use about 9,400 acre-feet of groundwater per year. When the fourth unit is completed, which has a capacity of 350 megawatts, an additional 4,100 acre-feet of groundwater will be required.

The 2,000 acre-feet of water withdrawal shown for fish and wildlife is basically that used by riparian vegetation. Only about 5 to 10 acre-feet of this amount is charged to evaporation.

There is presently no water charged to recreation in the study area. This, however, is projected to change under future conditions. A total of 550 acre-feet is shown for this purpose in 1990. This estimate remains constant throughout the other study periods, and is a result of evaporation from the Woodruff Lake. Woodruff Lake was once used for irrigation and was filled by diversion from the Little Colorado River. The diversion works have since become inoperable, and the lake is dry most of the time. Present plans are to reconstruct the dam and diversion works and to use the lake for recreation and irrigation.

Hopi (HOP)

The Hopi WUA lies north of the Little Colorado River and stretches across Navajo County and into Coconino County. It includes a portion of the Hopi and Navajo Indian Reservations, including most of the Painted Desert. Its main source of water is surface inflows from the Holbrook (37,150 acre-feet), Black Mesa (11,800 acre-feet), Chinle (8,100 acre-feet), Tuba City (9,800 acre-feet), and Bodaway Mesa (350 acre-feet) WUA's. (See Water Budget Map.) Most of this water, however, simply passes through the study area and is not put to beneficial use. Approximately 60,050 acre-feet are discharged into the Holbrook and Bodaway Mesa WUA's (see Water Budget Map). This is mainly due to a lack of surface storage within the area. Except for stock ponds, there is no surface storage in the study area.

Local runoff within the study area is very small in comparison to its drainage area size. This results mainly from a lack of precipitation, although the soil types are also a factor. The net surface runoff was

estimated at 15,450 acre-feet per year. Most of this water, and some of the inflow from other WUA's, is lost in transit; and never reaches the stream gage located near Cameron. It is estimated that approximately 18,650 acre-feet per year are lost in this manner. An additional 1,800 acre-feet of surface water is used by riparian vegetation located along the stream channels.

Other surface water withdrawals in the study area include 2,200 acre-feet charged to livestock. Most of this withdrawal is evaporation from stock ponds. Only about 270 acre-feet per year are actually consumed by the livestock, and part of this amount (50 acre-feet) is supplied from groundwater.

The major groundwater withdrawal in the study area is for M&I and rural domestic purposes. This amounted to about 500 acre-feet in 1975 and is projected to increase to 1,600 acre-feet by 2020. Most of this increase is due to an increase in rural population.

There is also a projected change in the surface water inflows and outflows for the study area. This change is a result of projected increases in surface water withdrawals in New Mexico and the enlargement or rehabilitation of the Ganado and Woodruff recreation lakes located, respectively, in the Chinle and Holbrook WUA's. These uses will decrease the amount of runoff available to the Hopi area.

Kaibito Plateau (KAI)

The Kaibito Plateau WUA is located in the northwest corner of the Little Colorado River Basin. This WUA actually extends outside of the river basin boundary, but the water budget was developed for only that portion of the study area that is located within the Basin. The total water supply for this area is very small, consisting of about 1,650 acre-feet of surface runoff and 100 acre-feet of pumped groundwater. Most of the surface runoff is discharged from the study area (see Water Budget Map). Only minor amounts are consumed by livestock; the rest is evaporated from stock ponds. Stock ponds provide the only surface storage available in the area.

The only groundwater withdrawal in the study area, except for about 10 acre-feet per year used by livestock, is for rural domestic purposes. This withdrawal is expected to increase from about 100 acre-feet in 1975 to about 400 acre-feet by 2020 (Tables 5-3 and 5-6).

Puerco-Zuni (PRZ)

The Puerco-Zuni WUA is located in Arizona along the stateline between Arizona and New Mexico, and near the central axis of the Little Colorado River Basin. A large portion of the water supply for this area originates as runoff in New Mexico and is shown in the water budget tables as inflow to the study area. This includes some of the inflow from the Chinle WUA. The total inflow, under 1975 conditions, was estimated at 27,150 acre-feet per year. (See Water Budget Map and Table 5-3.) In addition to surface water inflow, about 27,750 acre-feet of surface runoff originates from within the WUA. This gives a total surface water supply of about 54,900 acre-feet.

Most of the surface water, however, simply flows through the study area and is discharged into the St. Johns, Concho and Holbrook WUA's. The total outflow was estimated at 52,100 acre-feet per year under 1975 conditions. This means that only about 2,800 acre-feet of surface water per year were actually used within the study area. This included 1,300 acre-feet used by riparian vegetation; 200 acre-feet consumed by livestock for drinking, and 1,300 acre-feet estimated to be evaporated from livestock ponds.

The livestock ponds are the only known storage facilities located within the study area. There are approximately 360 stock ponds in the area, which store about 600 acre-feet of water on an average annual basis (Table 5-1). This is the total volume of water available after reducing the inflow for spillway discharge, seepage, evaporation, etc.

The major groundwater withdrawal in the study area is for irrigation. There are two irrigated areas in the study region. One is located near Chambers, and the other near Adama. About 1,700 acre-feet per year are withdrawn for this purpose.

Except for about 100 acre-feet used by livestock, the only other groundwater withdrawal was for M&I and rural domestic purposes. This was estimated at 150 acre-feet for 1975, and is projected to increase to about 400 acre-feet by 2020.

Other projected changes in the water budgets for this area occur in the surface water inflows and outflows. These changes will result from increased use of surface water flows in New Mexico and the enlargement or rehabilitation of Ganado Lake in the Chinle WUA (Tables 5-3, 5-4, 5-5 and 5-6).

San Francisco Peaks (SFP)

The San Francisco Peaks WUA encompasses the City of Flagstaff and the area north of the city to the Little Colorado River and west to the Basin's outlet. Most of the water that is available to this WUA is in the form of streamflow. This was estimated at 226,000 acre-feet per year under 1975 conditions. This consisted of 123,800 acre-feet of surface inflows and 102,200 acre-feet of surface runoff originating from within the study area (Table 5-3). A major part of this latter volume is springflow from Blue Spring and several other springs which effluent into the Little Colorado River. Only about half of the spring flow (80,700 acre-feet), however, was allocated to the San Francisco Peaks WUA: the other half is shown in the Bodaway Mesa Water Budget.

Most of the available streamflow (211,300 acre-feet per year) is discharged from the study area; and consists of about 206,900 acre-feet discharged into the Colorado River at the Basin's outlet; and 4,400 acre-feet which flows into the Canyon Diablo WUA along San Francisco Wash (see Water Budget Map). In addition, about 9,000 acre-feet are estimated to be lost in the main stem of the Little Colorado River.

Other losses include 400 acre-feet used by riparian vegetation and 50 acre-feet evaporated from a small wildlife reservoir. In addition 1,500 acre-feet

were estimated to be evaporated from about 416 livestock ponds, 200 acre-feet from four recreation reservoirs, and 1,400 acre-feet from four storage reservoirs owned and operated by the City of Flagstaff. This gave a total evaporation loss of about 3,150 acre-feet per year, under 1975 conditions, and compares with the estimated average annual storage of 9,200 acre-feet, which has been adjusted for evaporation.

Other surface water withdrawals include 170 acre-feet for irrigation at Doney Park, 110 acre-feet consumed by livestock for drinking and 1,850 acre-feet withdrawn by the City of Flagstaff for M&I and rural domestic purposes. The City of Flagstaff is the largest user of surface waters for M&I purposes in the Basin.

In addition to the surface water withdrawals for M&I and rural domestic purposes, approximately 2,300 acre-feet of groundwater were pumped for these purposes in 1975. The only other known groundwater withdrawal was for livestock consumption. This was estimated at 18 acre-feet in 1975 and is in addition to that used by livestock from surface water sources.

Groundwater withdrawals are projected to increase significantly in the future. The major use will continue to be for M&I and rural domestic purposes with minor amounts being withdrawn for livestock. Withdrawals for these purposes are expected to more than triple by the year 2020 to a value of approximately 7,650 acre-feet per year.

Some changes are also projected to occur in the surface water portions of the water budgets. These are basically the result of increased withdrawals from this source outside the San Francisco Peaks WUA. Only minor changes in surface water use are expected within the study area itself.

St. Johns (STJ)

The St. Johns WUA is located in Apache County and encompasses an area of about 670 square miles, including the Town of St. Johns. The largest water withdrawal in the study area is for irrigation and livestock. This amounted to about 27,200 acre-feet in 1975 (see Table 5-3). About 24,050 acre-feet of this amount were withdrawn for irrigation and 3,150 acre-feet for livestock. Most of these withdrawals were diverted from surface flows. Only about 735 acre-feet were pumped from groundwater; 700 acre-feet for irrigation and 35 acre-feet for livestock.

Surface waters which are not used for irrigation or other purposes are discharged into the Concho WUA. Discharges were estimated at 7,950 acre-feet per year under 1975 conditions.

Some of the surface waters for irrigation are diverted directly from streamflow at Richville, St. Johns, and Zion Reservoir. The flows at Richville are regulated, to some extent, by reservoir storage located outside the study area; i.e., within the White Mountain WUA. Major irrigation storage within the St. Johns area is in Lyman Lake and Little Reservoir. These two reservoirs store, on the average, about 12,250 acre-feet of water per year. The total storage capacity in the reservoirs, however, is much greater.

For example, Lyman Lake itself has a total capacity of about 30,600 acre-feet. The average annual storage for all reservoirs in the study area was estimated at 17,900 acre-feet and includes 236 acre-feet estimated to be stored in some 157 stock ponds.

Evaporation from the irrigation and livestock reservoirs is also charged against these purposes. It was estimated that 7,650 acre-feet were evaporated from the reservoirs under 1975 conditions: 4,200 acre-feet from irrigation reservoirs, 3,050 acre-feet from livestock ponds, and 400 acre-feet from Salado Springs. Although Salado Springs has no storage, as such, it consists of a wet meadow where evaporation losses are high. The meadow is used for grazing and flow from the springs is used by the St. John's Irrigation Company.

Most of the water shown as evaporated from the livestock ponds is from one reservoir. This is Zion Reservoir, which was originally constructed for irrigation storage; but has since become filled with sediment; and is presently being used as a sediment control structure and livestock reservoir. Since becoming filled with sediment, the lake is very shallow and evaporation losses are high. Evaporation from the lake has been estimated at nearly 2,500 acre-feet per year. About 560 acre-feet are estimated to be evaporated from the other livestock reservoirs. (6) (Note: Evaporation from Zion Reservoir was not included in Section 3, Rural Domestic and Livestock Water," since it was originally constructed for irrigation. Its present use is basically sediment control. Evaporation from the reservoir was charged to livestock in the Water Budget Analysis for convenience, since this is one of its present uses.)

By comparing the total water withdrawal for livestock (3,150 acre-feet) with the estimated evaporation from livestock ponds (3,050 acre-feet), it will be noted that only about 100 acre-feet of water are actually consumed by livestock within the WUA. (6)

Water withdrawals for M&I and rural domestic purposes in 1975 were also rather small (Table 5-3). This use, however, has more than doubled in the past few years and is projected to nearly triple by the year 2000 (Tables 5-3, 5-4 and 5-5). Recent increases in this water use is the result of the installation of the Coronado Steam Electric Power Plant. With the construction of the plant, the population and thus, the M&I water withdrawals have increased significantly in the area. Withdrawals for these purposes are supplied mostly from groundwater.

The installation of the Coronado Steam Electric Plant has not only caused an increase in water use due to increased population, but water withdrawals for electric power generation itself will also become quite significant under future conditions. Total withdrawals for this purpose are projected to increase from about 200 acre-feet in 1975 to 20,600 acre-feet by 1990 and 26,000 acre-feet by the year 2000. Withdrawals will then level off through the year 2020. The increased use includes 9,800 acre-feet for the Coronado plant (this is in addition to the 4,900 acre-feet imported from the Concho area) with the remainder being used by the Springerville plant

proposed for construction by the Tucson Electric Power Company. The power plants are projected to become the major users of groundwater in the study area.

The only other water withdrawals in this study area are those for fish and wildlife and for recreation. The water allocated to fish and wildlife is that used by riparian vegetation and a portion of the evaporation from Lyman Lake is charged against recreation. Although Lyman Lake is basically an irrigation structure, there is a minimum storage for recreation; therefore, a portion of the evaporation was allocated to this purpose.

Snowflake (SNO)

The Snowflake WUA is located along the southern edge of the Basin and includes the Towns of Snowflake and Taylor. This WUA is supplied from both groundwater (29,300 acre-feet) and surface water (25,150 acre-feet) (Table 5-3). About half of the surface water supply (12,600 acre-feet) is not used but is discharged from the study area.

The major uses of groundwater in the study area are for irrigation and major industry. Groundwater withdrawals for irrigation were estimated at 12,000 acre-feet in 1975 and 15,750 acre-feet were withdrawn by Soutwest Forest Industries for pulp mill operations near Snowflake. Other groundwater uses include 30 acre-feet withdrawn for livestock consumption; 700 acre-feet used for M&I and rural domestic purposes and 700 acre-feet for recreation.

In addition to the groundwater withdrawals for irrigation, about 8,300 acre-feet of surface waters are diverted annually for this purpose. This water is supplied from surface water storage and spring flow. Storage for irrigation is included in Martinez Lake, White Mountain Lake, Love Lake and Lone Pine. Because of seepage problems, Lone Pine remains dry most of the time. The most dependable reservoir for irrigation is White Mountain Lake or Daggs Reservoir. This lake is used to regulate surface runoff and a combined spring flow of about 11 cfs (7,950 acre-feet per year) from Silver Springs and other springs located above the structure. The average annual storage in the four reservoirs is about 5,800 acre-feet, excluding evaporation.

Evaporation from these structures was estimated at 3,000 acre-feet per year. This includes 2,500 acre-feet from White Mountain Lake and 500 acre-feet from the other three reservoirs. About 700 acre-feet of the evaporation from White Mountain Lake, however, is charged to recreation. This results from an agreement between the Show Low-Silver Creek Water Conservation and Power District and a land developer who is developing a subdivision near the lake. This agreement states that a minimum amount of storage will be retained in the lake for recreational purposes. Therefore, the net evaporation charged to irrigation is about 2,300 acre-feet per year.

The average annual storage is not adequate to meet the surface water needs for irrigation; thus, about 2,500 acre-feet per year are diverted directly from streamflow, (8,300 acre-feet estimated average annual diversion vs.

5,800 acre-feet average annual storage). Under future conditions, this storage deficiency will be alleviated to some extent by the enlargement of the reservoir on Little Mormon Lake and the improvement of its outlet conditions. Although this lake is located in the White Mountain WUA, the water stored in the reservoir will be used for irrigation in the Snowflake WUA.

Other storage facilities in the study area consist of 209 livestock ponds and 12 recreational structures. The total storage in these reservoirs was estimated at 900 acre-feet per year; 300 acre-feet in the stock ponds and 600 acre-feet in the recreational reservoirs. Evaporation from these reservoirs was charged to their respective purposes. Evaporation from the livestock ponds was estimated at 800 acre-feet per year, and 150 acre-feet per year were estimated to be evaporated from the recreation reservoirs. This gives a total evaporation loss of 850 acre-feet per year charged to recreation, (700 acre-feet from White Mountain Lake plus the above 150 acre-feet).

In addition to evaporation, there are approximately 700 acre-feet of groundwater pumped each year for recreation. These are waters pumped to operate and maintain several fishing lakes located in the study area. Although these withdrawals could be classified as a fish and wildlife use, they were identified by the U.S. Geological Survey as being pumped for recreational purposes and therefore are shown in the water budget tables under this category.

The only fish and wildlife use identified in the WUA is that used by riparian vegetation. This was estimated at 250 acre-feet per year under 1975 conditions (Table 5-3).

Water used for M&I and rural domestic purposes in 1975 was estimated at 700 acre-feet. This use is projected to increase to about 1,900 acre-feet by 2020. This is the only change expected to occur in the water budgets for the study area. The supply for these uses, under both present and future conditions, is groundwater.

Tuba City (TUB)

The Tuba City WUA is located on the Navajo Reservation in the northwest corner of the river basin and includes the Town of Tuba City. The water supply for this area is relatively small in comparison to that for some of the other water use areas. The total water supply was estimated at only 11,850 acre-feet per year under 1975 conditions. This includes 10,650 acre-feet of surface inflow from Kaibito Plateau, Hopi and Bodaway Mesa WUA's (see Water Budget Map). The surface runoff within the study area is very small and was estimated at only 250 acre-feet per year. This low yield results from low precipitation and from the fact that over half of the area has been identified as contributing little or no runoff to the Little Colorado River. (See map entitled, "Areas Which Contribute Little or No Streamflow to the Little Colorado River,".) Water supplied from groundwater was estimated at 950 acre-feet (Table 5-3).

Of the total surface waters available, approximately 9,800 acre-feet are discharged downstream to the Hopi WUA (see Water Budget Map). The major use of surface water within the study area is for irrigation and livestock (900 acre-feet). This includes about 340 acre-feet evaporated from storage reservoirs, 530 acre-feet diverted for irrigation and 30 acre-feet consumed by livestock. The only other use of surface water in the study area is 200 acre-feet estimated to be used by riparian vegetation. This use is shown under the fish and wildlife category of Table 5-3.

The major use of groundwater in the Tuba City area is for M&I and rural domestic purposes. Minor amounts (8 acre-feet per year) are used by livestock. The groundwater used by livestock, however, does not show up in the water budget tables due to rounding and the groundwater supply is made equal to the withdrawals for M&I and rural domestic purposes. Withdrawals for these latter purposes are expected to increase from about 950 acre-feet in 1975 to about 2,500 acre-feet by the year 2020 (Tables 5-3 and 5-6). This is the only significant change expected to occur in the water budgets for the study area.

White Mountain (WHM)

The White Mountain WUA is located in Apache and Navajo Counties, along the southern edge of the Basin. Most of the water withdrawals in the study area are supplied from surface water. Only about 2,250 acre-feet (rounded) of groundwater were pumped in 1975 (Table 5-3).

Most of the groundwater withdrawals (1,905 acre-feet) were used for M&I and rural domestic purposes. About 310 acre-feet were withdrawn for irrigation and 15 acre-feet for livestock.

On the average about 35,400 acre-feet per year of the surface waters, which originate within the study area, are discharged downstream to the St. Johns, Concho and Snowflake WUA's (see Water Budget Map). In addition, about 3,300 acre-feet are pumped from Show Low Lake into Forestdale Creek in the Salt River Basin. The export from Show Low Lake is being made by the Phelps-Dodge Corporation, a copper mining company, on the basis of an exchange agreement with the Salt River Project.

Surface waters used for irrigation are stored in some 39 irrigation reservoirs and released on an as-needed basis or are diverted directly from streamflow as water supply is available. The average annual storage in the reservoirs is estimated to be about 11,850 acre-feet. This compares with an annual surface water withdrawal for irrigation of about 23,450 acre-feet. These figures indicate that over half of the surface water withdrawals for irrigation are diverted directly from streamflow. Also, some of the surface waters stored within the area for irrigation are actually used outside the study area.

Evaporation from the irrigation reservoirs is also charged against this purpose. This amounts to about 3,300 acre-feet per year.

Evaporation from livestock ponds is a major water use within the study area. It was estimated that about 1,400 acre-feet per year are evaporated from some 386 reservoirs constructed specifically for this purpose. In addition, 600 acre-feet were charged to livestock for evaporation from some larger reservoirs used for watering livestock. Only about 137 acre-feet per year are actually consumed by livestock. This includes the 15 acre-feet supplied from groundwater.

Other evaporation losses within the study area include 50 acre-feet from two waste treatment ponds located near Show Low; 450 acre-feet from Show Low Lake; and 1,000 acre-feet from 18 other reservoirs used mainly for fish and wildlife purposes. The evaporation from the waste treatment ponds is classified as a municipal use and is included in the M&I and rural domestic category of Table 5-3. Evaporation from Show Low Lake is shown in Table 5-3 as a major industrial use because of the exchange agreement between the Phelps-Dodge Corporation and the Salt River Project. In addition to the 1,000 acre-feet of evaporation from the fish and wildlife reservoirs, about 250 acre-feet are charged to these purposes for water use by riparian vegetation growing along the stream channels.

The final evaporation loss identified in the study area is charged to recreation. Withdrawals for this purpose were estimated at 800 acre-feet per year and consist solely of evaporation from seven recreation reservoirs.

The only change projected to occur in the water budgets for the WUA is for M&I and rural domestic purposes. Withdrawals for these purposes are expected to increase from about 1,950 acre-feet in 1975 to about 4,900 acre-feet by the year 2020. A major part of this increase results from increased population at Springerville and Eagar due to the construction of the Springerville power plant by the Tucson Electric Power Company. The projected increased withdrawals are expected to be furnished from groundwater.

NEW MEXICO

Carrizo Wash (CAR)

The Carrizo Wash WUA uses only about five percent of the New Mexico total. Agriculture is the major water user, but with irrigation water use playing a lesser role than in the Zuni WUA. Agriculture water use is projected to decrease slightly in the future but there is a projected increase in mining activity in the area. Mining is projected to become the major water user by 1990 (Table 5-4).

Upper Puerco (UPR)

Ignoring surface water outflows, the Upper Puerco WUA uses about 35 percent of the total water used in the New Mexico portion of the Basin. The largest use is for M&I and rural domestic water, which shows the influence of the City of Gallup. The population of Gallup is expected to increase nearly six times by the year 2020. This will result in even greater influence on the water use for this area in the future (Tables 5-3, 5-4, 5-5 and 5-6). About 7,500 acre-feet of the future use will be supplied by

surface imports from the San Juan River Basin. Other alternatives for supplying future water needs are described in Reference 5, listed in back if this section of the appendix.

Zuni (ZUN)

The Zuni WUA uses about 60 percent of the total water used in the New Mexico portion of the Basin. The largest use is for agricultural purposes, mostly irrigation. Also, because of its relatively large irrigation use, the Zuni area is the largest user among the three New Mexico WUA's. Agricultural water use is projected to increase largely because the Zuni Indians expect to increase their irrigation by rehabilitating their storage facilities and distribution system. The meager stream gage data indicate that the projected increases cannot be met with surface water alone; some groundwater will have to be pumped for all water use projections to be met. Water use for M&I and steam electric power generation are expected to increase by the year 2000.

TOTAL BASIN

The water budget for the total Basin is simply an accumulation of the water budgets for the individual WUA's. With reference to surface inflow, however, care must be taken in order to prevent double counting. Surface inflows are simply exchanges of water between the various study areas within the Basin and are balanced by surface outflows. The net water supply available to the Basin is equal to the accumulation of surface runoffs plus groundwater withdrawals. The net water supply was estimated at 628,800 acre-feet per year under 1975 water development conditions (Table 5-3).

With reference to surface outflows, caution is again in order and no attempt should be made to add the outflows in a vertical direction in the tables. For here again some of the values would be double counted. The net export from the Basin is equal to the net water supply (runoff and groundwater) minus the sum of all water withdrawals shown in the tables. That is, the net export from the Basin is equal to the net water supply minus the net water use within the Basin. The net export (and/or outflow) was estimated to be 359,800 acre-feet per year under 1975 conditions. (See footnote 10 at the bottom of Table 5-3.) About 345,600 acre-feet are discharged to the Colorado River at the Basin's outlet, 3,300 acre-feet are pumped from Show Low Lake to Forestdale Creek and 10,900 acre-feet are diverted from the Blue Ridge Reservoir to the East Verde River (see Water Budget Map).

The total water withdrawn for irrigation and livestock within the Basin was estimated at 151,450 acre-feet per year. Except for minor changes in New Mexico, this value remains relatively constant throughout the study periods. It consists of 112,000 acre-feet of water withdrawn for irrigation, 2,750 acre-feet used by livestock for drinking and other purposes, and 36,700 acre-feet evaporated from irrigation and livestock reservoirs.

Water withdrawals for M&I and rural domestic purposes were estimated at 20,550 acre-feet per year under 1975 conditions (Table 5-3). Most of this

water was supplied from the groundwater reservoir. Only about 3,350 acre-feet were withdrawn from the surface water supply, and 1,430 acre-feet of this amount was evaporation from M&I reservoirs. This use is expected to more than triple by the year 2020 to a value of about 64,950 acre-feet per year. Similar to present conditions, most of the increase will be supplied from groundwater, except for about 7,500 acre-feet of surface water projected to be available to the City of Gallup, New Mexico, by the year 2000 from the San Juan River Basin.

The total water withdrawal for major industry in 1975 was estimated at 25,200 acre-feet. This was used for pulp mill operations near Snowflake, Arizona; coal mining operations in the Black Mesa Area; evaporation from Show Low Lake, Blue Ridge Reservoir and Dry Lake; and other mining operations located in New Mexico. Water withdrawal for these purposes are expected to increase to about 36,250 acre-feet by 2020. Most of the increase is projected to occur in New Mexico.

Water withdrawals for steam electric power generation were relatively minor in 1975 consisting only of about 3,550 acre-feet. This use, however, is projected to increase to more than 50,000 acre-feet by the year 2020 Most of this increase will occur in Arizona with the construction of two new power plants; one near St. Johns and the other near Springerville. The St. Johns Power Plant is already under construction with the first unit beginning production in 1979. The capacity of an existing generating station (Cholla Power Plant) at Joseph City is also scheduled to be increased. A steam electric generating station is also projected to be constructed in the Zuni WUA in New Mexico by the year 2000. All water for this purpose is projected to be supplied from groundwater.

Most of the water withdrawn for fish and wildlife purposes is supplied from surface water resources. Withdrawals for these purposes amounted to 15,450 acre-feet in 1975 and are projected to increase to 22,650 acre-feet by 2020 (Tables 5-3 and 5-6). These withdrawals are basically evaporation from storage reservoirs and water used by riparian vegetation. The water used by riparian vegetation was estimated at 10,000 acre-feet per year in 1975 and is projected to remain relatively constant. The projected increases for fish and wildlife will result from increased evaporation from new or improved reservoirs constructed for these purposes. Most of these reservoirs will be located in the New Mexico portion of the Basin.

Except for about 700 acre-feet of groundwater pumped for recreation in the Snowflake WUA, all withdrawals for this purpose (10,850 acre-feet) were evaporation losses from recreational reservoirs. These are reservoirs which have been identified as having recreation as their major purpose. The slight increase in water use projected for this purpose is a result of increased evaporation from new of improved reservoirs constructed for this purpose.

The only other water withdrawals identified in the water budget analysis were the channel losses occurring along the Little Colorado River from

Holbrook to Cameron. These losses amount to about 41,950 acre-feet per year. There are other channel losses occurring within the river basin, but since adequate gaging station records are not available, these losses could not be positively identified, but have been accounted for in the budgets by adjusting the "Net Surface Runoff" values shown in the water budget tables.

WATER QUALITY

Water quality is a relative term and is dependent upon the use to be made of the water. For example, water that is of adequate quality for agricultural purposes may not be adequate for M&I or rural domestic purposes. Water quality, therefore, can and does affect the total water supply that is available for a particular purpose. It is not the intent of this section, however, to estimate the supply based on quality, but simply to estimate the total supply that is available from all sources. It was assumed that water of adequate quality will be available for the projected purposes in the selected WUA's. In most instances, this has already been determined.

For this reason and since water quality for specific purposes has been addressed in other sections of this appendix, it will not be discussed further at this time. The reader is referred to Section 1 for a discussion of water quality as related to irrigation; and to Sections 2 and 3 concerning the quality of water being used for M&I and rural domestic and livestock purposes. The reader is also referred to Reference No. 1, for a complete discussion of a water quality management plan for the Arizona portion of the Little Colorado River Basin, developed by the Arizona Department of Health Services.

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